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(Eds.)



ICT in Education, Research and Industrial Applications

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This volume represents the proceedings of the Workshops co-located with the 16th International Conference on ICT in Education, Research, and Industrial Applications, held in Kharkiv, Ukraine, in October 2020. It comprises 101 contributed papers that were carefully peer-reviewed and selected from 233 submissions for the five workshops: RMSEBT, TheRMIT, ITER, 3L-Person, CoSinE, MROL. The volume is structured in six parts, each presenting the contributions for a particular workshop. The topical scope of the volume is aligned with the thematic tracks of ICTERI 2020: (I) Advances in ICT Research; (II) Information Systems: Technology and Applications; (III) Academia/Industry ICT Cooperation; and (IV) ICT in Education.

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Preface

In these extraordinary and challenging times, it is our great pleasure to present you the proceedings of the Workshops co-located with ICTERI 2020, the sixteenth edition of the International Conference on Information and Communication Technologies in Education, Research, and Industrial Applications, held in Kharkiv (Ukraine) on October 5-10, 2020. This year's edition focused on research advances, information systems technologies and applications, business/academic applications of Information and Communication Technologies. Emphasis was also placed on the role of ICT in Education. These aspects of ICT research, development, technology transfer, and use in real world cases remain vibrant for both the academic and industrial communities. Overall, ICTERI 2020, including the Workshops, was focused on the four thematic tracks reflecting these research fields: (i) ICT research advances, (ii) information systems technologies and applications, (iii) academic and industry cooperation in respect to Information and Communication Technologies, and, more relevant than ever, (iv) the role of ICT in Education.

This volume is structured in six parts, each presenting the contributions to a particular workshop:

Part I: RMSEBT Workshop is the fourth workshop Rigorous Methods in Software Engineering and Blockchain Technologies. The workshop was organized by Vladimir Peschanenko, Mykola Nikitchenko, and Yulia Tarasich. The workshop dedicated to rigorous methods which are used in different fields of software engineering: rigorous methods for specification, verification and optimization of software, rigorous methods for different kinds of software analysis (modeling, business rule extraction etc), software testing which based on rigorous methods (model based testing, white box testing and so on), re-engineering problems (model extraction from source code, language migration etc), DLT architecture development, modeling and verification of token economies, detected of smart contracts vulnerability.

Part II: TheRMIT Workshop is the sixth workshop on Theory of Reliability and Markov Modelling for Information Technologies. The workshop was organized by Vyacheslav Kharchenko. The workshop dedicated to overcoming a gap between researchers of mathematical methods for reliability, safety, security and dependability as a whole, on the one side, and engineers who develop critical systems, auditors who assess and assure dependability during life cycle stages, on the other side.

Part III: ITER Workshop is the eighth workshop on Information Technologies in Economic Research. The workshop was organized by Vitaliy Kobets, Tetiana Paientko, and Alessio Maria Braccini. The workshop intended for providing a meeting point for intensive scientific exchange among researchers and experts from computer science, business computing and information system areas in emerging technologies interested in a focused look into IT in economic research related to the design, development, implementation, use and management of emerging technologies, real-world business applications and the move to a digital economy.

Part IV: 3L-Person Workshop is the fifth workshop on Professional Retraining and Life-Long Learning using ICT. The workshop was organized by Oleksandr Burov and Svitlana Lytvynova. 3L-Person Workshop intended for providing for evaluating new and emerging technologies in education, learning environments and methods that have

to satisfy life-long learning of a person (from school age to retirement), professional training and retraining in view of the person-oriented approach. It covers such topics as an adaptive learning strategy and design, day-to-day support for individual's learning, life-long learning of individuals, learning at the workplace, learning with emerging ICT that provide remote collaboration, learning/training process of individuals with special needs, ICT in education safety and security, recommendation regards vocational re-training and/or further carrier etc.

Part V: CoSinE Workshop is the eighth workshop in memory of Illia O. Teplytskyi on Computer Simulation in Education. The workshop was organized by Arnold Kiv, Serhiy Semerikov, Vladimir Soloviev, and Andrii Striuk. CoSinE Workshop is a regular peer-reviewed workshop co-located with ICTERI focusing on theory and practice of computer simulation in education. CoSinE puts special emphasis on real-world applications of computer simulation in education. Therefore, all contributors are strongly encouraged to demonstrate how and for what purpose the proposed solutions are to be used. Examples could be taken from case studies involving new tools and/or methodological approaches in education, experimental studies with usable learning applications, or surveys revealing new modelling tools in educational research and practice.

Part VI: MROL Workshop is the fourth workshop on Methods, Resources and Technologies for Open Learning and Research. The workshop is organized by Hennadiy Kravtsov and Mariya Shyshkina. MROL Workshop intended for benchmarking the state of the art and defining the future prospects of the open systems of higher education design and development, with the focus on the most valuable trends, methods, tools and technologies driving the innovative development of educational environment. It focuses also on the learner' competencies needed for the open educational and research systems development including higher responsibility, collaborative skills, leadership, creative thinking, taking the problem in general and others are to be considered and explored.

Overall, ICTERI 2020 workshops attracted 223 paper submissions. Out of these submissions, the organizers have accepted 101 high quality and most interesting papers. So, the average acceptance rate was of 43,3 percent.

This volume would not appear without the support of many people. First of all, we would like to thank all the authors who submitted papers to the workshops of ICTERI 2020 and thus demonstrated their interest in the research problems within their scope. We are very grateful to the members of the Program Committees for providing timely and thorough reviews and, also, for being cooperative in doing additional review work. We would like to thank the local organizers of the conference whose devotion and efficiency made the constellation of ICTERI 2020 workshops a very interesting and effective scientific forum.

October 2020 Oleksandr Sokolov, Grygoriy Zholtkevych, Vitaliy Yakovyna,
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Global Digital Identity and Public Key Infrastructure

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Abstract. This paper proposes the concept of building a decentralized identification system that allows each participant to perform the role of both an identity object and an identity provider, regardless of their technical and legal capabilities. The main parameter of significance in the system is the level of trust toward the subject by the other participants of the platform and external IDs information consumers. This maintains the ability to fully manage the account and associated PII for their owner through the use of a cryptographic signature mechanism: changes to key data, PII and identifiers can be made at any time. The proposed system does not change the existing model of trust for large providers of identification services, but it allows to increase the objectivity of information about identifiers and PII of their owners by the possibility of verification of a separate identifier to each of the participants of the platform, followed by recording the results of verification in the chain of blocks. The use of blockchain technology and a consensus-reaching mechanism make it possible to synchronize the sequence of events in the system. The described global digital identity system positions itself as a source of information about global entities of specific subjects, and related personal data sets and established identifiers, while allowing the end-user of information to make independent conclusions about the level of trust of these identifiers based on related transactions. The system described is compatible with the digital asset management infrastructure and current identification tools. Thus, the system accomplishes a number of important tasks: reducing the threshold for using digital identifiers, allowing their ubiquitous use; the ability to verify the identifier and prove its compliance without the need to build a trusted infrastructure (only cryptography and other participants' votes); reducing the likelihood of certificate substitution attacks; increase the objectivity of information about the identifiers used.

Keywords: Blockchain, Digital Identity System, Public Key Infrastructure.

1 Introduction

Today, the usual point is the independent verification of user credentials by each system individually (or by an organization to which the system owner has entrusted user identification). Very often, these methods are not very different from each other: users transmit the same set of personal data, confirm registration using traditional methods (mail, phone, etc.), as a result of which they receive a “local” identifier that is valid only within the boundaries of the selected system.

The main disadvantage of this approach is that the user must go through the same identification and registration process again and again, even if an identical data set is provided. In addition to the resource costs of these processes, this entails that identifiers obtained in different systems are in no way interconnected: information about identifiers and PII confirmations is not synchronized between identity providers, which in some cases can lead to the use of different identifiers to manipulate user permissions. Moreover, at the same time, the data is not stored in a single unified format and is not signed by the user when they are transferred, which entails the difficulty of finding the custodian of certain data and the inability to confirm their integrity and authenticity.

Global services such as Google [1], Facebook [2], Twitter [3], GitHub [4] and others allow users to sign in to other services through the OAuth protocol [5-8], but this protocol does not provide the required cryptographic reliability and uses session mechanisms to gain access to user data [9]. Existing decentralized payment systems have shown that the best practice is the cryptographic signature of each request sent to the accounting system and the signature of each response that the system returns [10].

The global digital identification system involves binding all user’s PII and his public key (as an option - a set of keys) to a unique global identifier. Where it leads:

- All information about confirmations of personal data is stored in a single system. Using mechanisms of digital signature and linking transaction sets to each other will ensure the authenticity of specific PII confirmations with time-bound events;
- The integrity and authenticity of the data binded to the account is checked exclusively by cryptographic methods (control root hash value);
- The management of personal data is completely controlled by its owner, all other participants in the system can only confirm a user-defined data set. To obtain personal data about a particular participant in the system, an identity provider must contact him directly and obtain either the necessary data set or permission to receive this data from another identity provider.

2 Global identifier and data associated with it

A global identifier is a unique entity within the identification system that represents a specific subject and is associated with information identifying this subject. The identifier is bound to: the public key of the owner of the identifier, a set of hash values from the identifiers of other accounting systems, as well as a set of hash values from PII,

which is tied to the account owner. All of the listed data is linked into one structure - an account (see Fig. 1).

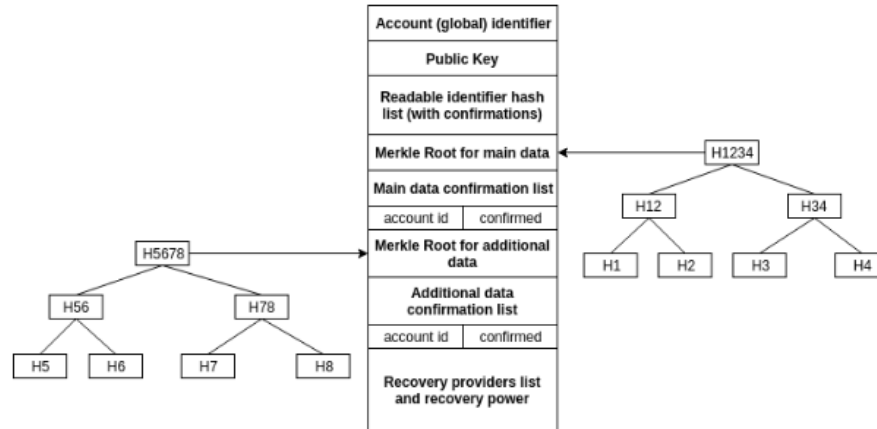


Fig. 1. Account structure in decentralized digital identity system.

“Account (global) identifier” is an immutable and unique value within the identification system, represented as a byte string. This value is generated when the identity provider creates the new user’s account. The main requirement is the uniqueness of this value within the system (this can be either randomly generated or not randomly selected).

“Public key” is a public key value, with the private key of which all transactions initiated by a particular account are signed.

“Readable identifier list” is a set of hash values from identifiers in other systems, such as email address, facebook id, etc. Also, each hash value is associated with a specific set of confirmations from other network members that they checked that the account owner owns the specified email, facebook_id, etc., which correspond to the specified hash values.

“Merkle Root for main data” is the root value from the user’s main set of personal data [11]. It is assumed that the values included in this set will not be updated frequently and therefore they will remain confirmed even if other account fields are changed.

“Main data confirmation list” consists of a set of records consisting of the identifier of the provider and information about the set of main data they have verified.

“Merkle Root for additional data” is the root value of an additional set of user personal data. It is assumed that the values that are included in this set will change, and correspond to confirmations more often than the main set.

“Additional data confirmation list” consists of a set of records consisting of the identity of the provider and information about the set of additional data they have verified.

“Recovery providers list and recovery power” determine the set of identity providers (and their amount) needed to restore access to the account and change the public key.

3 Transactions and blocks

The global digital identification system provides that each participant (who has an account) can send a transaction to the network. Transactions are stored as an ordered set of blocks (see Fig. 2), each of which contains a cryptographic hash value of the previous one [12], which provides the ability to control the integrity of the entire history of events associated with global identifiers.

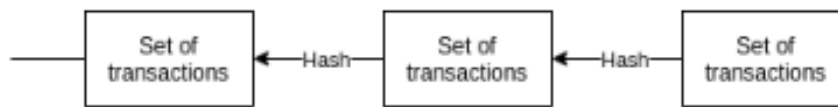


Fig. 2. Transactions arranged as a linked chain of blocks.

A transaction, in turn, consists of a set of defined operations. There are four main types of operations: the operation of creating an account; the operation of changing / adding data associated with a specific global identifier; confirmation operations of data associated with the identifier; the operation of restoring access to the account (changing the public key and the set of parties for recovery).

The account creation operation can be initiated by any existing account. As a result of the operation, a new account is created in the identification system and its identifier and public key are determined (you can additionally define fields containing hash values of personal data and their confirmations).

Data change operations include operations whose purpose is to change / add main and additional personal data of the user, as well as change the values of identifiers associated with external systems. Such transactions can only be signed by the account owner and verified using the public key value specified in the account. In fact, each user personally determines the data set that he wants to associate with the global identifier; identity providers, in turn, have the right only to confirm the data set by the user.

Data verification operations include operations whose purpose is to confirm main and additional personal data. Such transactions can be sent by identity providers (in fact, by any member of the network) in relation to a particular account. Such a transaction contains information about the identifier of the account to which the confirmation is carried out, about the value of Merkle Root, to which the data verified by it belongs, as well as about the set of data itself that has been verified.

The operation to restore access to the account can only be signed by the owners of the identifiers that were defined by the user at the time of creating or updating the account. In fact, the user personally determines the set of trusted parties (and their required number), which can confirm his identity and sign the transaction to update

the public key of the account. In fact, carrying out all types of operations described constitutes the life cycle of the account (see Fig. 3).

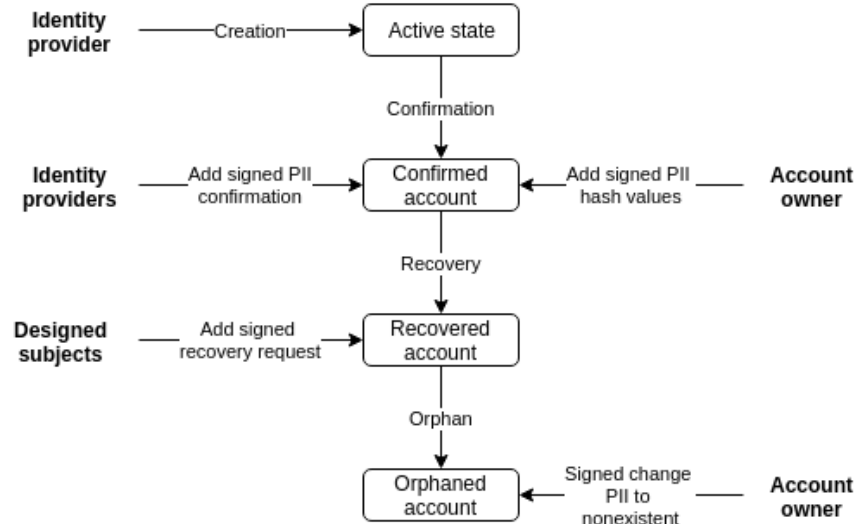


Fig. 3. Account lifecycle.

3.1 Account creation process

In order to create an account in the global digital identity system, the user needs to contact with identity provider. This can be either a separate independent entity, or tied to a specific accounting system. The registration process may differ depending on the individual provider (this can be either the personal presence of the user or remote registration), but it is worth identifying its main features [13]. In the process of creating an account, the user provides the provider with a set of personal data that must be confirmed, the Merkle Root value from the entire data set, as well as the Merkle Branch value to prove that the particular set is in the root value [11]. This allows the provider to check only specific data and agrees that they are included in the general set, and all this without providing the entire set of personal data.

Also, the user needs to generate a key pair (private and public keys) and confirm ownership of the specified email address (or other identifier, depending on those specified in the account). The account creation process is shown in the following diagram (see Fig. 4).

1. The user sends the identity provider a set of personal data that must be confirmed, the Merkle Root value for the entire personal data set, Merkle Branch as evidence that the personal data set is included in the root hash value, public key, email address and the generated identifier value. The user also defines a list of accounts that can change the value of the public key and restore access to the account.

- The identity provider checks the provided personal data and checks their relation to the root value.

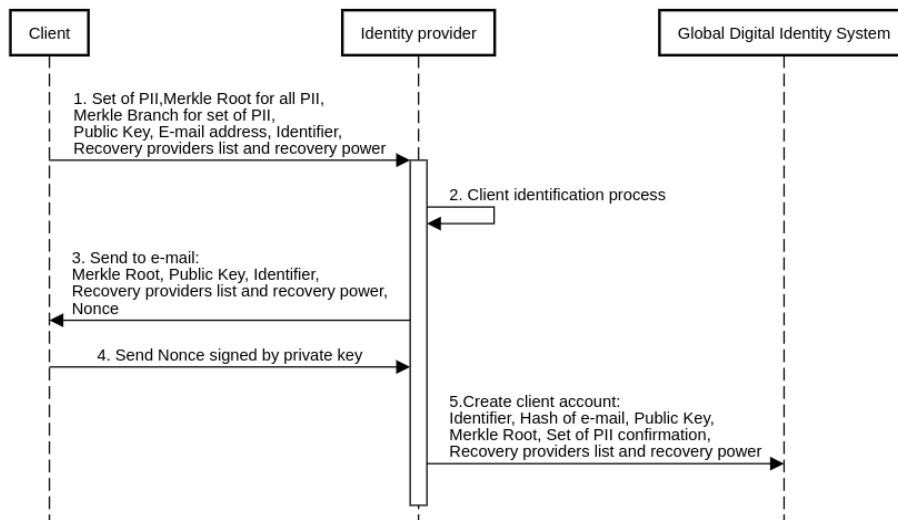


Fig. 4. Process of registration and account creation.

- The registrar sends a e-mail confirmation to the client (not necessary e-mail, another channel can be used). The confirmation contains Merkle Root (proof that the data received by the provider was not modified), the received public key (also that it was not modified), identifier, list of trusted providers and Nonce value. All values are signed by the provider's key; accordingly, an attack on message modification during transmission is excluded.
- The user receives a mail, checks that all the data is valid, then signs the Nonce value with his own private key (as proof that he owns the public), and then sends the signed value to the provider.
- The registrar verifies the signature, after which it initiates the creation of the account: it fills out the necessary fields, generates a global identifier and sends the corresponding transaction.

3.2 PII confirmation process

After the user account has been created, the user determines the set of personal data that will be associated with his account (if he did not define it during creation). He collects the data in the structure of the Merkle tree and puts the root value in the account. As we noted earlier, the account contains two Merkle Root values: for a set of basic data and additional. This approach will leave the master data confirmed, even if the additional ones are changed.

After the user has determined the personal data, he needs to receive confirmation of this data from identity providers. It is important to note that the user may not want

the provider to gain access to the entire set of his personal data. This property can be provided by using Merkle trees. In this case, in the process of confirming personal data, the user must not transfer their entire set so that the provider checks their integrity and authenticity, but only the data necessary for verification and the Merkle Branch value to prove that they are in the root value (see Fig. 5).

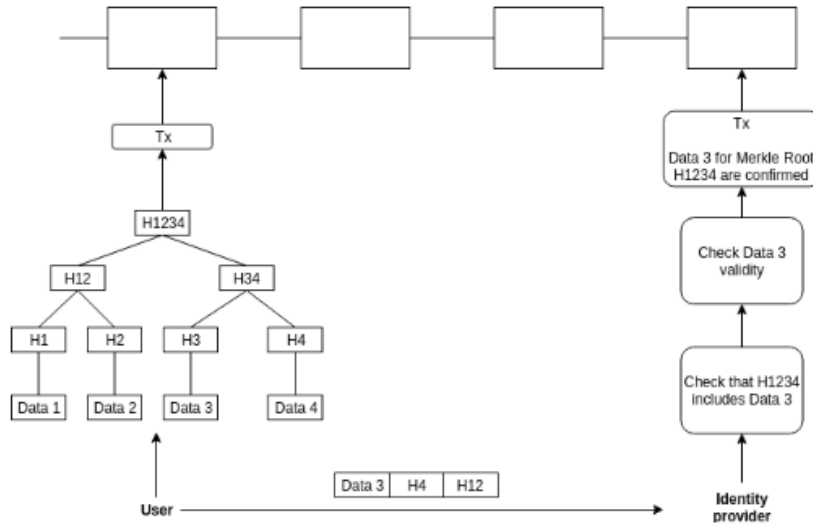


Fig. 5. The user adds his data to the Merkle tree structure, and then updates the account data. When confirming this data, they pass to the identity provider the required set and Merkle Branch for the root value.

When the identity provider receives the data set and Merkle Branch from the user, he checks that the received data matches the root hash value specified in the account, and then checks the received data. If the provider agrees with the data received, it forms a transaction, which indicates that it has confirmed a specific set of personal data that relates to a specific account identifier and a specific Merkle Root value.

If the user decides to update part of the data for a full set, in this case, the value of Merkle Root will completely change. As a result, a previously sent transaction that confirms the data for a particular Merkle Root becomes invalid. That is why the structure of the account implies dividing the data into main and additional: if the user has confirmed the basic data set (and does not change it), then regardless of whether the additional data has been updated, the basic data will remain confirmed.

3.3 Decision making regarding identifier trust

An important feature of such a system is the independent decision-making regarding the identifier by the consumer of information. There is no information in the system that directly determines the validity of a particular identifier: there are only accounts and votes confirming the data of these accounts. Thus, the issue of trust is submitted

entirely to the client side. In this case, he can personally determine the methodology, which will be described when calculating the level of trust.

One of the methods for determining trust is the number of identifier confirmations by other network participants. However, it should be borne in mind that this method is subject to a Sybil attack - one of the account can create a large number of other accounts that confirm the identity of one of the participants in the system [14].

The second approach is to trust only a specific provider (several providers). For example, being a client of a bank, I trust its identification mechanisms and can set up my site in such a way as to trust only those accounts that have been verified by the said bank. Although this scheme is somewhat centralized (if the number of providers that the user trusts is small), it will be quite effective and expected, most used due to its simplicity.

In the third case, if the objectiveness of the result is really important for the network member, he can build complex verification algorithms that evaluate both the level of trust for providers who confirmed a specific account and providers who confirmed accounts with a specified provider (thus up to a large number of verification levels).

It is important to note that whichever way the consumer uses identification results, the system provides the ability to fully customize the verification algorithm, which lies solely on the client side.

4 Permissions to the PII receive

In order to meet the GDPR policy, it is necessary that PII users are transferred and processed only with the permission of their owners [15]. If personal data is transmitted directly by the user to the provider, everything is quite simple: when establishing a connection, the user gives permission to process his personal data. However, difficulties arise if the registrar does not request data directly from the user, but from the party that has previously authenticated it (for example, the user does not keep all the necessary data for registration on the service, however, this data was previously confirmed by the registrar and, accordingly, from him are stored).

Since the provider that stores PII users cannot distribute this data without first obtaining permission to do so, this permission must be provided by the user. Such permission must contain the date and time of its formation, the identifier of the PII owner's account, the set of data that is allowed to be transferred to the second party, as well as the identifier of the recipient side. Note that the request must be signed with a private key that is tied to the user's account.

If the registrar receives a similar request from the user, he checks the signature value of the request using the public key that is specified in the user's account. If the signature is valid, then he looks at what set of personal data is requested, and if he really has the required set of personal data, then he sends them and the Merkle Branch value to the requesting party (they must first establish a secure channel). The requesting party carries out a procedure similar to that described in 3: it checks that the received data is in the root hash value, and then confirms the personal data.

The timestamp in the request is necessary to ensure the confidentiality of the updated PII. If the user has updated his personal data set and does not want the party that previously received permission to access the old set to be able to receive updated data for the same permission. Therefore, when checking permission, the registrar compares the time of sending the transaction with the updated data and the time for obtaining permission, and if the time for obtaining permission is shorter, then access to personal data of users is not provided.

5 Consensus reaching and security assumption

Using a native currency for the network to motivate validators and using proof-of-work / proof of stake mechanisms for reaching consensus is not the best solution, since the quality of identification information and the reliability of the system, as practice has shown, will completely depend on the “value of this currency” [12; 16]. Moreover, a completely anonymous environment is not the most suitable for the construction of an identification system, where the level of confidence of the identification will depend on the processing power or the size of the stack of registrars, which does not exactly indicate their competence in issues of user identification.

It is not worth changing the model of trust relations to specialized providers of identification services, but you only need to expand it by combining these providers into a single network, which will contain information about issued identifiers and their confirmations. At the same time, leading identity providers will act as public sources of information about confirmed data, which will in no way affect the change in attitudes towards them. In other words, trusting the identification of a particular organization, you also continue to trust it, however, it no longer acts as an identifier provider for a specific local field, but as an identifier provider in the global system, which automatically expands the user area of activity. Thus, having confirmed the identifier with several major suppliers, the user gets rid of additional identification in local systems that trust these providers.

The most suitable model for achieving consensus for this system is the FBA algorithm [17], which is actually a projection of trust relationships between network participants at its level. Thus, the largest service providers will benefit from launching validator nodes and setting up communication between each other. Thus, each of them will be able to provide relevant information on the status of user identifiers, and relations between global suppliers will not allow one / several parties to cheat: in this case, there is a big risk of being outside the main quorums of the system, resulting in loss of trust from end users and using system identifiers.

The key issue at this stage is protection against spam attacks [18-22]: they cannot affect the decision-making mechanism regarding a specific identifier, since if a user trusts only a number of providers, they can (and should) be ignored by the voices of other participants in the system (this way we protect from the attack of Sybil); however, at the same time, since any user can add a transaction to the network, and in fact the number of such transactions is not limited, this can negatively affect the system’s throughput, therefore, a mechanism for protecting against this from the validators

should be provided (for example, receiving rewards for adding transactions in the block - the same mempool, however, each registrar personally agrees with customers regarding the method of payment; we repeat that the internal currency in such a system should be absent).

6 Conclusions

Existing public key infrastructures were the first step in digitizing interactions between Internet users, which involved providing basic information services [23-28]. They showed that this interaction can be accomplished using cryptographic methods based on user certificates. However, such approaches are still not ubiquitous, since it is rather difficult to associate valid (in various accounting systems) user identifiers with their certificates. Integration is difficult when it comes to technical and legal compatibility (including the signature algorithms used), the need for direct trust in certification services, and problems associated with synchronizing information related to the creation / renewal / revocation of certificates.

The implementation of the identification system functioning scheme described in the document does not imply a mandatory abandonment of the existing X.509 infrastructure. Moreover, the simple integration of existing certificates is supposed by adding them to the account structure. The key idea of such a system consists precisely in transferring control of data into the hands of their owners and unifying access to various services through the use of cryptographic methods [29-33]. When user data is tied to a specific key, ownership of which proves the authenticity of the subject, only then can the system be sure of the authenticity of the requester.

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The Computational Modeling: Dynamic Quantum Model Approach

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Abstract. After S. Smale's works it became clear that in smooth dynamics the system of a general form is not structurally stable and therefore there is no strict mathematical basis for modeling and computational analysis of systems. The contradiction appeared in science: according to physicists dynamics is simple and universal. The solution to this problem was proposed based on the construction of dynamic quantum models (DQM). From the assumption that quantum effects are caused by unrecoverable "white noise", a certain mathematical model of quantum mechanics already follows and is essentially unambiguous. On the other hand, in this model spectral problems are reduced to the usual perturbation theory of smooth dynamical systems. Thus, the construction of such models can be considered as an asymptotic method for solving spectral problems. But the definition of DQM is not formally related to Hamiltonian systems. DQM is defined and constructed universally for both Hamiltonian systems and systems with the truth function. As a result, for example, quantization with the Bohr-Sommerfeld condition also extends to systems with a truth function. Hopefully DQM opens for new applications. The most important is to seek assistance and cooperation in future research.

Keywords: modeling, computer simulation, structural stability, dynamical system, dynamic quantum model, Markov cascade.

1 Introduction

Increasingly, processes and systems are researched or developed through computer simulations and this trend is likely to continue [1]. Computational modeling has been used in physics, chemistry and related engineering for many decades because this is the only way the equations can be solved at all [2]. It consists from two steps: (i) modeling, i.e. finding a model description of a real system, and (ii) solving the resulting model equations using computational methods [3].

But if an arbitrarily small perturbation of the model leads to a qualitatively different picture of the dynamics, then such a model is not applicable to the real process: strictly speaking, perturbations are included in the definition of a model [4]. Also computational methods inevitably lead to errors of discretization and rounding in calculations [5]. Therefore traditionally the stability of a model with respect to rela-

tively small changes is a necessary condition for its correctness [6]. The qualitative invariance of a mathematical model under small perturbations is usually called structural stability [7].

However, in S. Smale's works [8] was shown, that there exist smooth dynamic systems whose neighborhoods do not contain any structurally stable system. This meant that there was no rigorous mathematical basis for modeling and computational analysis. The contradiction has appeared in science, because physicists believe that the dynamics is simple and universal [9].

The solution to this problem was proposed in [10] based on the construction of dynamic quantum models (DQM). It turned out that taking into account random fluctuations, necessary for the transition to the quantum model of reality, allows us to return in fact to the simple picture of A. Poincaré's dynamics: a dense set of structurally stable systems.

DQM is so named because for Hamiltonian systems it is simply related to the corresponding Schrödinger equation. From the assumption that quantum effects are caused by unrecoverable "white noise", a certain mathematical model of quantum mechanics already follows and is essentially unambiguous [11]. Dynamics in it is described by Markov cascades (time is discrete). This model is simply connected with the traditional one: there is a simple correspondence between Markov cascades and quasisolutions of the corresponding Schrödinger equation. Thus, in a sense, DQM is a bridge between the formal calculus of quantum mechanics and the intuitive vision of physicists. On the other hand, in this model spectral problems are reduced to the usual perturbation theory of smooth dynamical systems. Thus, the construction of such models can be considered as an asymptotic method for solving spectral problems. This paper gives an example of such approach to the one-dimensional system with the quasiperiodic potential (Proposition 2).

But the definition of DQM is not formally related to Hamiltonian systems; it is defined for any ordinary differential equation or any diffeomorphism on any smooth Riemannian manifold. Hopefully this opens the way for absolutely new applications. For example, for applications to dynamic systems that using logical operations: algorithms, theorems, software applications. The use of fuzzy logic in DQM is in principle completely natural and even almost inevitable. Let $J = J(z)$ be a given smooth function on phase space ($0 \leq J(z) \leq 1$), equal to 1 on the true trajectory and 0 outside some neighborhood of it; we can interpret it as the function of truth. In this paper, DQM is defined and constructed universally for both Hamiltonian systems and systems with the truth function J . As a result, for example, the point of the DQM spectrum is interpreted exactly as the average value of truth for approximate logical conclusions. Quantization with the Bohr-Sommerfeld condition also extends to systems with a truth function (Proposition 1).

But the reverse is also true. If we construct an approximate model of given theorem or software application using the training of a neural network, then we get the DQM of these objects. With further training, these DQMs will approach the original object (in other words, they will converge to it according semiclassical limit). Perhaps this will allow a new approach to the problems of solvability in logic, there is some analogy with the theorem of the equivalence of structural stability and hyperbolicity proved

in [10]. DQM of systems with logical operations are always uniformly limited by the number of operations (see Section 2.2) and then for them solvability is not in doubt. Then everything depends on the semiclassical limit, more precisely, on the uniformity of the structural stability of DQM.

The **paper goal** is 1) to build the foundations of the theory of dynamic quantum models (DQM); 2) to demonstrate the application of this theory for spectral problems of quantum mechanics.

The paper is organized as follows: in part 2 we synthesize the dynamic quantum model (DQM); in part 3 we demonstrate the application of DQM for spectral problems of quantum mechanics; part 4 concludes.

We had to omit proofs of some propositions in order to fit the paper format.

2 The Dynamic Quantum Model: Basic Definitions

2.1 DQM Definition

Let $p(x)$ be an n -dimensional smooth vector field on an n -dimensional smooth Riemannian manifold M , where $x(x_1, x_2, \dots, x_n)$ are local Euclidean coordinates on M , $p_i(x) \in C^\infty(R^n)$ ($i=1, \dots, n$). On each phase curve $x(t) \in M$ of the dynamical system generated by this vector field

$$\frac{dx_i}{dt} = p_i(x), \quad (i=1, \dots, n) \quad (1)$$

consider the integral of the “shortened action” $s(t) = \int_{x(t)} p(x) dx = \int_0^t \|p(\tau)\|^2 d\tau$,

where $\|p(\tau)\|^2 = \sum_{i=1}^n p_i^2(\tau)$. The value of $s(t)$ on each curve $x(t)$, which is different from a fixed point, is diffeomorphically expressed in t and is called “optical time”. Let ρ be a metric such that $s(t) = \int_{x(t)} d\rho: d\rho = \|p(t)\|^2 dt$. The following is

the heuristic derivation or explanation of the definition of dynamic quantum model (Definition 1).

So, the distance d traveled by a point along the path of (1) during the time Δt is equal to $d = \int_0^{\Delta t} \|p(\tau)\| d\tau = \|p(t_c)\| \cdot \Delta t$, where $p_c = p(t_0)$ is the average value ($0 \leq t_0 \leq \Delta t$). (Of course this is with a single bypass of trajectory during Δt : turning points are the special case). Further, we assume that the fluctuations generate “white noise” $\xi(t)$, acting on the configuration space with the dispersion $D\xi(t) = \sigma^2 t$, where the diffusion coefficient σ^2 is constant over the considered time interval. It

will take some time Δt , until the point moves to a distance d from the initial position, which exceeds the mean square error caused by $\xi(t)$ during the time Δt , i.e. $\|p_c\|\Delta t$ will exceed $\sqrt{\sigma^2\Delta t}$. With such a minimal Δt $\|p_c\|\Delta t = \sigma\sqrt{\Delta t}$, whence $\sigma^2 = \|p_c\|^2 \Delta t$ and therefore

$$\Delta t = \frac{\sigma^2}{\|p_c\|^2}, \quad d = \|p_c\|\Delta t = \sigma\sqrt{\Delta t} = \frac{\sigma^2}{\|p_c\|}. \quad (2)$$

Here by assumption Δt is the minimal time interval after which it becomes possible to make a new measurement, the difference from which will exceed the error, i.e. get a significantly different measurement. Owing to (2)

$$\sigma^2 = \|p_c\|^2 \Delta t \approx \int_0^{\Delta t} \|p(\tau)\|^2 d\tau = s(\Delta t). \text{ Thus 1) the time interval between the}$$

nearest significant measurements is unchanged on the optical time scale and is equal to σ^2 . (In other words, the distance between them in the metric ρ is equal to σ^2).

2) During this time “white noise” $\xi(t)$ generates an irremovable random error, the standard deviation of which is equal to the distance d between the nearest significant measurements along the trajectory.

Now suppose that the configuration space is one-dimensional, there is a turn point on the segment of the trajectory, the initial position is located near the turn point and move towards it. To pass a segment of the path, the ends of which are significantly different, the point must reach the turning point, and then (after turning) pass another segment of ρ – length σ^2 . How much will the distance to the nearest significantly different measurement increase? The points on the segment ρ – lengths σ^2 , including the turning point, are indistinguishable among themselves, only their average value is important. Therefore, the points in the interval between $\frac{3}{2}\sigma^2$ and $\frac{1}{2}\sigma^2$ to the turning

point in time σ^2 will move to the segment centered just on the turning point; and after a while until the next significantly different position. So, only for points on a segment with length $\frac{1}{2}\sigma^2$ to a turning point, the distance to the nearest significantly

different measurement will increase: on average by $\frac{1}{4}\sigma^2$.

In the general case, one should take into account those points that move towards the caustic K – the set of singular points at which the direction of motion changes and are located at ρ – distance $\frac{1}{2}\sigma^2$ from K . To pass a segment of the path, the ends of which are significantly different, such points must reach K , and then (turning) to pass another segment of ρ – length σ^2 in a new direction. Therefore, the travel time

for these points will increase on average by $\frac{1}{4}\sigma^2$. The jump in the time interval at turning points on the optical time scale is a quantum-mechanical phenomenon traditionally taken into account by means of the Morse index (when establishing a connection with the Schrödinger equation, it turns out that $\frac{1}{4}\sigma^2 = \frac{\pi\hbar}{2}$, i.e. $\sigma^2 = 2\pi\hbar$).

Generally speaking, there may be features on the caustic other than turn points, however, such a singular point splits into several turn points with an arbitrarily small stir [6]. At such points, the number $\frac{1}{4}\sigma^2 \cdot \mu = \mu \frac{\pi\hbar}{2}$ is added to the ρ -length, where μ is the Morse index of the singular point. Here μ is an integer equal to the number of turning points that arose during small stir and passed in the positive direction to the caustic minus the number of turning points traveled in the negative direction.

So, a dynamic quantum model first shifts each point along the phase curve of a given dynamic system over the optical time σ^2 (or ρ -length σ^2) and in a neighborhood of the caustic this shift increases abruptly by $\frac{1}{4}\mu\sigma^2 = \mu \frac{\pi\hbar}{2}$.

And then randomly shifts on a distance not exceeding the length of the trajectory from the original to the new point. The following rigorous definition summarizes this description. The definition of a dynamic quantum model is given for an arbitrary dynamic system (1) on an arbitrary compact Riemannian manifold M .

Definition 1. By a dynamic quantum model (DQM) for dynamical system (1) we mean the Markov cascade with the transition function $P(x, A)$, which associates with each point x of the trajectory of (1) and an open subset A of the configuration space probability of getting from x to A in one iteration:

$$P(x, A) = \frac{1}{\sqrt{2\pi t} \sigma} \int_A e^{-(y-Gx)^2/2\sigma^2 t} dy,$$

where t is the shift time from x to Gx along the path of the ρ -length $2\pi\hbar$ or $2\pi\hbar + \mu \frac{\pi\hbar}{2}$ in the neighborhood of the caustic, $\sigma^2 = 2\pi\hbar$. Given the initial distribution, we obtain a Markov process P with this initial distribution and the transition function $P(y, A)$: if μ_t is the distribution at time t , Δt is the lag between the two nearest measurements, then the DQM sets new distribution $P(\mu_t) = \mu_{t+\Delta t}$ at time $t + \Delta t$.

2.2 DQM Eigenvalues and Markov Deviations

Our goal is to determine pure states and eigenvalues of DQM. And now, along with the discreteness of the measurement process, its limited time will be essential. Of course, the measurement process cannot continue indefinitely, but here its duration is dictated by the very definition of DQM. Namely, the duration of the measurement, in

principle, cannot exceed on order $\frac{1}{h}$ since further the measurement errors with dis-

persion $\sigma^2 t$ (where the diffusion coefficient σ^2 is small of order h) are no longer small and the notion of trajectory loses its meaning. (And you can only talk about the average values for the ensemble, as in statistical physics). Therefore, we limit the time to a certain limiting value T of order $\frac{1}{h}$ ($T \sim \frac{1}{h}$): $T \leq \frac{B}{h}$, where $B > 0$ is a con-

stant. (In general, we say that the quantity $u = u(h)$ in a DQM is of order h^k ($u \sim h^k$ or $u = O(h^k)$), if $|u| \leq Ch^k$. And $u = u(h)$ is exactly of the order h^k ($u \sim h^k$), if $ch^k \leq |u| \leq Ch^k$ for some constants $C, c > 0$).

Let us now consider the problem: it is required to experimentally determine the location of the point at which a given point of the phase space $(x; p)$ passes under the action of dynamical system (1) with the greatest possible accuracy. Note that the time interval between the two nearest significant measurements is $\sigma^2 = 2\pi\hbar$ on the optical time scale or of order $\frac{h}{\|p\|^2}$ on the usual scale in the neighborhood of the point $(x; p)$

(see (2)). In addition, the duration of the measurements is limited by the value of $T \sim \frac{1}{h}$. Therefore, the position of the point in the next significant measurement can be

obtained, in principle, only a finite number of times, namely $N \sim T \frac{h}{\|p\|^2} \sim \frac{\|p\|^2}{h^2}$

numbers. But this position is determined each time with the unrecoverable error, the standard deviation of which is equal to $d \approx \frac{\sigma^2}{\|p\|}$ (see (2)), i.e. $d \sim \frac{h}{\|p\|}$. Therefore,

the averaging of all such measurements, i.e. then the best approximation to the unperturbed value, which in principle can be achieved, differs from it by an order of value $\frac{d}{\sqrt{N}} \sim \frac{h}{\|p\|} \sqrt{\frac{\|p\|^2}{h^2}} \sim \frac{h^2}{\|p\|^2}$. Such a deviation is given at each point z of the

phase space, i.e. defines a vector field $Z(z)$. So,

1. h^2 is the least in order error, with which the coordinates of the point in the phase space can be known, and thus the values observed at the point. Values whose difference in order of value is less than h^2 are not experimentally distinguishable.
2. As a result of averaging the maximum number of maximally accurate measurements, we arrive to a dynamical system generated not by the diffeomorphism G , but by its perturbation $\bar{G} = G + Z$.

Definition 2. The Markov deviation $Z(z)$ is a smooth vector field on phase space such that 1)

$$\|Z(z)\| \leq B \frac{h^2}{\|p\|^2}$$

($B > 0$) is a constant of dynamical system (1) (i.e., the length $Z(z)$ does not exceed in order $\frac{h^2}{\|p\|^2}$ for all points z of the phase space);

2) for any initial point $z_0 = z(t_0)$ on the phase curve $z(t)$ of the dynamical system (1) and the time instant \bar{t} in optical time ($|\bar{t}| < T \sim \frac{1}{h}$) we have

$$\left| \int_{t_0}^{\bar{t}} \left(\int_{t_0}^t (Z(z(s), e(s)) ds) dt \right) \right| \leq Bh^2, \quad (3)$$

where $e(t)$ is the unit normal vector of the closed phase curve at the point $z(t)$, $B > 0$ is the constant of dynamical system (1).

Property (3) of the Markov deviation is due to the fact that, by construction, the vector $Z(z(t))$ has a random orientation, therefore, the pluses and minuses of the accumulations of its projections on the unit vectors are compensated. Therefore, the integral of the accumulation of projections along the phase curve is experimentally indistinguishable from zero.

If instead of a given time limit $T \sim \frac{1}{h}$ we take $T_1 \sim \frac{1}{h}$ ($T_1 \neq T$), then we obtain another Markov deviation; similarly, when replacing the zero point in time. So the Markov deviation is a smooth vector field that depends on the parameters; further, it can be assumed to be a general view field.

2.3 DQM Pure States and Eigenvalues. Quantization of Spectrum in DQM.

The physical meaning of the eigenvalues is that these are all values of energy that can be the result of reliable, i.e. the most accurate measurement (ideally of the order of h^2). But as a result of the most accurate experiments, as we have seen, in reality the dynamics is studied not of the diffeomorphism G , but of its perturbation $\bar{G} = G + Z$. Let $J = J(z)$ be a given smooth function on phase space. We can interpret it as the Hamiltonian (energy in the phase space) or as a function of truth ($0 \leq J(z) \leq 1$), equal to 1 on the true trajectory and 0 outside some neighborhood of it. Given the irremovable errors of the Markov deviation, the discreteness of the measurement process and its limited time, we arrive at the maximum number of the most accurate measurements $\frac{1}{N_t} \sum_{i=0}^{N_t} J(\bar{G}^i z)$, where z is the point of phase space, Z is the general view

Markov deviation, $\bar{G} = G + Z$ is a diffeomorphism, N_t is the maximum number of significantly different measurements over time $t \leq T$.

In terms of meaning the eigenvalue of the spectrum is associated with some pure stationary state of the dynamical system: any reliable measurement in this state leads to an acceptable error (ideally with a maximum accuracy of the order of h^2) and only

to this value. But in a DQM any point in the phase space is always known with the irremovable error of order h (see (2)). As a result, we average generally speaking over trajectories with a starting point not z , but some \tilde{z} , that is distant from z by a distance of the order h . Therefore, the carrier of the state associated with some eigenvalue of α must contain a ball with a diameter of exactly the order of h : otherwise, any reliable experiment with a significant probability will lead to values significantly different from α . Hence

Definition 3. Let $\bar{G} = G + Z$, where Z is a general view Markov deviation; N_t is the number of all iterations of the diffeomorphism in time t ; α is a real number. Let $D_{\alpha h}$ be the set of points z of the phase space such that for all sufficiently large $t < T \sim \frac{1}{h}$

$$\left| \frac{1}{N_t} \sum_{i=0}^{N_t} J(\bar{G}^i z) - \alpha \right| < Bh^2,$$

where B is a constant. Then, if for any Z of a general view and sufficiently small h , the set $D_{\alpha h}$ contains a ball with a diameter of exactly the order of h , then α will be called the eigenvalue of the DQM for dynamical system (1), and $D_{\alpha h}$ will be called the carrier of the pure state corresponding to this eigenvalue.

Thus, all points of a DQM spectrum are formally determined only with an accuracy of the order of h^2 , but this corresponds precisely to their meaning. By definition, the domain $D_{\alpha h}$ is an open \bar{G} -invariant subset of the phase space.

So, to define DQM means to set: 1) the Markov process in accordance with Definition 1; 2) the Markov deviation Z of general view or, what is the same, diffeomorphism $\bar{G} = G + Z$ in accordance with Definition 2.

Consider the two-dimensional dynamical system (1), the compact phase space Λ of which is filled with closed phase curves. After the smooth change of variables, in canonical coordinates, this is the dynamics of uniform rotation along concentric circles. If we interpret J as a function of truth, then its values on each circle, concentric to the true path (true circle), are constants (i.e., they do not depend on a point on this circle). At the semantic level, with such interpretation, we are talking about transitions to equivalent propositions.

Proposition 1. The DQM eigenvalues of the given dynamical system, with accuracy of the order h^2 , are equal to the values of $J(z)$ on the phase circles in Λ , the ρ -length of which satisfies the Bohr - Sommerfeld condition

$$\int p(x) dx = \pi I = \pi h \left(n + \frac{1}{2} \right)$$

and only they.

3 The Spectrum of Schrödinger Equation with Quasiperiodic Potential and DQM

Consider the Schrödinger equation

$$ih \frac{\partial \psi}{\partial t} = H(\psi) = -h^2 \frac{\partial^2 \psi}{\partial x^2} + U(x)\psi \quad (4)$$

with the quasiperiodic potential $U(x) = \cos x + \varepsilon \cdot \cos \lambda x$ ($\varepsilon, \lambda > 0$). For this Schrödinger equation we construct its dynamic quantum model (DQM), i.e. in accordance with Definition 1, the perturbation of the corresponding classical system by the Markov process. There is a simple connection between these Markov processes and the quasisolutions of the Schrödinger equation. The connection between the Schrödinger equation and the corresponding DQM is based on a following modification of the traditional asymptotic expansion of solution (4).

Lemma 1. Let $\psi(x, t) = \varphi(x, t) e^{\frac{i}{h} S(x, t)}$ is some quasisolution (4), i.e.

$$ih \frac{\partial \psi}{\partial t} = H(\psi) = -h^2 \frac{\partial^2 \psi}{\partial x^2} + U(x, t)\psi + O(h^2),$$

where $\varphi(x, t) = \varphi_h(x, t)$ and $S(x, t) = S_h(x, t)$ are real-valued. Then

$$\left(\frac{\partial S(x, t)}{\partial t} + \left(\frac{\partial S(x, t)}{\partial x} \right)^2 + U(x) - h \frac{\partial^2 S(x, t)}{\partial x^2} \right) \varphi(x, t) - h \left(\frac{\partial \varphi(x, t)}{\partial t} + 2 \frac{\partial S(x, t)}{\partial x} \frac{\partial \varphi(x, t)}{\partial x} - h \frac{\partial^2 \varphi(x, t)}{\partial x^2} \right) = O(h^2). \quad (5)$$

The converse is also true: if $S(x, t) = S_h(x, t)$ and $\varphi(x, t) = \varphi_h(x, t)$ is some

quasisolution (5), then $\psi(x, t) = \varphi(x, t) e^{\frac{i}{h} S(x, t)}$ is some quasisolution (4).

Now we show how the DQM of the Schrödinger equation is constructed from its two-dimensional classical analogue

$$\frac{dx}{dt} = p \quad \frac{dp}{dt} = -\frac{dU}{dx}. \quad (6)$$

Let us consider separately the terms of equation (5): Hamilton-Jacobi perturbed equation

$$\frac{\partial S(x, t)}{\partial t} + \left(\frac{\partial S(x, t)}{\partial x} \right)^2 + U(x) - h \frac{\partial^2 S(x, t)}{\partial x^2} = 0 \quad (7)$$

and the Einstein-Fokker-Planck diffusion equation

$$\frac{\partial \varphi(x, t)}{\partial t} + 2 \frac{\partial S(x, t)}{\partial x} \frac{\partial \varphi(x, t)}{\partial x} - h \frac{\partial^2 \varphi(x, t)}{\partial x^2} = 0, \quad (8)$$

in which $S(x, t)$ is determined from (7). If for $S(x, t)$ (7) holds with an accuracy of order h^2 and for $\varphi(x, t)$ (8) holds with an accuracy of order h , then the function

$\psi(x, t) = \varphi(x, t) e^{\frac{i}{h} S(x, t)}$ satisfies (4) with an accuracy of the order h^2 , i.e. it is a quasisolution of the Schrödinger equation.

According to section 2.3 the DQM of the Schrödinger equation is determined by 1) the smooth dynamics from (7) and 2) its stochastic perturbation from (8).

1) Consider the first two terms of the asymptotic expansion of the solution $S(x, t)$ of equation (7) with respect to the small parameter \hbar :

$$S(x, t) = S_0(x, t) + \hbar S_1(x, t) + O(\hbar^2). \quad (9)$$

Substituting this expansion into (7), in a first approximation, we obtain the Hamilton - Jacobi equation

$$\frac{\partial S_0(x, t)}{\partial t} + \left(\frac{\partial S_0(x, t)}{\partial x} \right)^2 + U(x) = 0$$

On the trajectory (6) γ with the energy level $\alpha = -\frac{\partial S_0(x, t)}{\partial t}$, this equation takes the form

$$\left(\frac{\partial S_0(x, t)}{\partial x} \right)^2 + U(x) = \alpha. \quad (10)$$

The velocity on γ is $\frac{\partial S_0(x, t)}{\partial x} = \pm \sqrt{\alpha - U(x)} = \pm p_0(x)$ regardless of t . Assuming that $S_1(x)$ is also independent of t , we find from (7) outside the turning points \bar{x} ($\frac{\partial S_0(\bar{x}, t)}{\partial x} = 0$)

$$\frac{\partial S_1}{\partial x} = \frac{1}{2} \frac{\partial^2 S_0}{\partial x^2} \bigg/ \frac{\partial S_0}{\partial x} = \frac{1}{2} \frac{\partial}{\partial x} \ln \left| \frac{\partial S_0}{\partial x} \right|. \quad (11)$$

Now the smooth DQM dynamics corresponding to the perturbed Hamilton - Jacobi equation (7) is defined by the system:

$$\frac{dx}{dt} = \frac{\partial S}{\partial x} = \frac{\partial S_0}{\partial x} + \hbar \frac{\partial S_1}{\partial x} = \pm p_0(x) + \hbar \frac{\partial S_1}{\partial x}; \quad \frac{dp}{dt} = -\frac{dU}{dx},$$

where in \hbar - neighborhoods of turning points we smooth $S_1(x)$, preserving it with an accuracy of the order of \hbar .

2) DQM also includes stochastic disturbance, “white noise” in the configuration space. If each point x_0 , in accordance with the smooth dynamics of the DQM, moves along the trajectory (6) during time Δt to the point $x = x_0 + \int_{t_0}^{t_0+\Delta t} \frac{\partial S}{\partial x}(x(\tau), \tau) d\tau$;

and at this time scattering occurs, defined by the normal distribution with the dispersion Δt , then [12] the distribution density $\varphi(x, t)$ at the time $t = t_0 + \Delta t$ is a solution of the diffusion equation

$$\frac{\partial}{\partial t} \varphi(x, t) = -\frac{\partial S(x, t)}{\partial x} \frac{\partial \varphi(x, t)}{\partial x} + \frac{\sigma^2}{2} \frac{\partial^2 \varphi(x, t)}{\partial x^2}. \quad (12)$$

This equation is equivalent to (8): if $\varphi(x, t)$ is a solution of (8), then this is a solution of (12) for $\sigma^2 = h$.

Let $H(\gamma)$ be the energy value on the trajectory (6) γ . Consider the integral of “shortened action” on $\gamma(t) = (x(t), p(t)) : s(t) = \int_{\gamma(t)} p(x) dx = \int_0^t \|p(\tau)\|^2 d\tau$. On

each trajectory $\gamma(t)$ other than a fixed point, the quantity $s(t)$ is diffeomorphically expressed through t and is called the optical time. Let ρ be a metric such that $s(t) = \int_{r(t)} d\rho : d\rho = \|p(t)\|^2 dt$. For a closed trajectory $\gamma(\gamma(0) = \gamma(\bar{\tau}))$ $2\pi I(\gamma) = s(\bar{\tau}) = \int_{\gamma} p(x) dx$ is ρ -length of this trajectory, i.e. optical time of its bypass.

Lemma 2. For all sufficiently small h , the eigenvalue α of equation (4) with accuracy of the order of h^2 is equal to the value of the energy $H(\gamma)$ on some closed path (6) γ . These and only these trajectories γ are such, for which the Bohr - Sommerfeld condition holds with accuracy of order h^2 :

$$I(\gamma) = h\left(n + \frac{1}{2}\right) \quad (n = 0, 1, \dots). \quad (13)$$

Proof. Suppose that, on a closed trajectory (11) γ , (13) holds. Using the DQM construction, we show that $\alpha = H(\gamma)$ is the eigenvalue of equation (4) with an accuracy of the order of h^2 . Let $S_0(x, t)$ be the action on γ , i.e. the solution of the Hamilton - Jacobi equation (10) on $\gamma \left(\frac{\partial S_0(x, t)}{\partial x} \right)^2 + U(x) = \alpha = H(\gamma)$. As the initial condition for $S_0(x, t)$ we take

$$S_0(x, 0) = \int_{x_0}^x p_0(y) dy, \quad (14)$$

where $p_0(y) = \sqrt{\alpha - U(y)}$ is velocity on γ , $p_0(x_0) = 0$, i.e. x_0 is the abscissa of the turning point on γ . Then

$$S_0(x, t) = S_0(x, 0) - \alpha t + k_t \cdot \pi I, \quad (15)$$

where k_t is the number of turns in time t , πI is the ρ -length by γ between turning points. And for $S(x, t) = S_0(x, t) + hS_1(x, t)$, where in accordance with the construction of DQM $S_1(x, t) = S_1(x)$ from (11), equality (12) is approximately satisfied:

$$\frac{\partial S(x, t)}{\partial t} + \left(\frac{\partial S(x, t)}{\partial x} \right)^2 + U(x) - h \frac{\partial^2 S(x, t)}{\partial x^2} = O(h^2). \quad (16)$$

We assume that the velocity function $p_0(x)$ on the closed curve γ without loss of generality is analytic with an accuracy of the order of h^2 , otherwise approximating $p_0(x)$ on γ analytic with this accuracy. Then outside the neighborhood of the turning points this is also true for $S_0(x, t)$, $S_1(x)$, and in the neighborhood of the turning

point $S_1(x)$ we can continue analytically. When turning, the sign of $\frac{\partial S_0(x,t)}{\partial x} = \pm p_0(x)$ changes, which in view of (11), implies the transition $S_1(x)$ to another branch of the logarithm. This means adding to the value of the logarithm, $\frac{1}{2}\pi i$ to S_1 and then $\frac{1}{2}\pi h i$ to S . Therefore, in view of (15)

$$S(x,t) = S_0(x,t) + hS_1(x,t) = S(x,0) - \alpha t + k_t(\pi i + \frac{\pi h i}{2}), \quad (17)$$

where, as in (17), k_t is the number of turns in time t .

By definition, DQM also includes a stochastic perturbation defined on γ by equation (12) with a diffusion coefficient $\sigma^2 = h$. Let $\varphi_0(x)$ be the density of the stationary state for such a process. Then, for such dynamics at the initial density $\varphi_0(x) = \varphi(x, 0)$, the solution of (12) $\varphi(x, t)$ is different from $\varphi_0(x)$ by order h for any finite time t : $\varphi(x, t) - \varphi_0(x) \sim h$ (due to scattering by “white noise” outside the limits of γ). Thus

$$\frac{\partial S(x,t)}{\partial x} \frac{\partial \varphi_0(x)}{\partial x} - \frac{h}{2} \frac{\partial^2 \varphi_0(x)}{\partial x^2} = O(h),$$

which is equivalent to this option (8):

$$\frac{\partial \varphi_0(x)}{\partial t} + 2 \frac{\partial S(x,t)}{\partial x} \frac{\partial \varphi_0(x)}{\partial x} - h \frac{\partial^2 \varphi_0(x)}{\partial x^2} = O(h). \quad (18)$$

Now replace h by hi in (18), (17) and (16). Then

$$\frac{\partial \varphi_0(x)}{\partial t} + 2 \frac{\partial S(x,t)}{\partial x} \frac{\partial \varphi_0(x)}{\partial x} - ih \frac{\partial^2 \varphi_0(x)}{\partial x^2} = O(h), \quad (19)$$

$$\frac{\partial S(x,t)}{\partial t} + \left(\frac{\partial S(x,t)}{\partial x} \right)^2 + U(x) - hi \frac{\partial^2 S(x,t)}{\partial x^2} = O(h^2), \quad (20)$$

$$S(x,t) = S(x,0) - \alpha t + k_t(\pi i - \frac{\pi h i}{2}). \quad (21)$$

Let on γ $\bar{S}(x) = S(x,0)$ to the first turning point and $\bar{S}(x) = S(x,0) + \pi i - \frac{\pi h i}{2}$

then to the second. Then $S(x,t) = \bar{S}(x) - \alpha t + m_t(2\pi i - \pi h i)$, where m_t is the number of complete walks γ in time t , $k_t = 2m_t$ or $k_t = 2m_t + 1$. Hence

$$e^{\frac{i}{h}S(x,t)} = e^{\frac{i}{h}(S(x,0) - \alpha t + k_t(\pi i - \frac{\pi h i}{2}))} = e^{\frac{i}{h}(\bar{S}(x) - \alpha t + m_t(2\pi i - \pi h i))} = e^{\frac{i}{h}(\bar{S}(x) - \alpha t)} \quad (22)$$

since by condition (13) $2\pi i - \pi h i = 2\pi h i(n + \frac{1}{2}) - \pi h i = 2\pi h i n$ ($n = 0, 1, \dots$). Let

$$\psi(x,t) = \varphi_0(x) e^{\frac{i}{h}S(x,t)} = \varphi_0(x) e^{\frac{i}{h}(\bar{S}(x) - \alpha t)} \in L^2. \quad (23)$$

In virtue of (19) and (20)

$$\begin{aligned} & \left(\frac{\partial S(x,t)}{\partial t} + \left(\frac{\partial S(x,t)}{\partial x} \right)^2 + U(x) - \hbar i \frac{\partial^2 S(x,t)}{\partial x^2} \right) \varphi(x,t) - \\ & - \hbar i \cdot \left(\frac{\partial \varphi_0(x)}{\partial t} + 2 \frac{\partial S(x,t)}{\partial x} \frac{\partial \varphi_0(x)}{\partial x} - \hbar i \frac{\partial^2 \varphi_0(x)}{\partial x^2} \right) = O(\hbar^2). \end{aligned} \quad (24)$$

Continuing this motion, we multiply by $e^{\frac{i}{\hbar} S(x,t)}$ both sides of (24). But then from Lemma 1, with the same accuracy of order \hbar^2 , (4) also holds for the function (23):

$$\hbar i \frac{\partial \psi}{\partial t} = -\hbar^2 \frac{\partial^2 \psi}{\partial x^2} + U(x) \psi + O(\hbar^2).$$

Hence in view of (23)

$$\alpha \cdot \varphi_0(x) e^{\frac{i}{\hbar} \bar{S}(x)} = \mathbf{H}(\varphi_0(x) e^{\frac{i}{\hbar} \bar{S}(x)}) + O(\hbar^2), \quad (25)$$

where $\mathbf{H} = -\hbar^2 \frac{\partial^2}{\partial x^2} + U(x)$ is Schrödinger operator. Equality(25) means [7] that the

pair $(\alpha, \varphi_0(x) e^{\frac{i}{\hbar} \bar{S}(x)})$ is quasisolution (quasimode) of the stationary Schrödinger equation $\alpha \psi = \mathbf{H} \psi$ with a small parameter \hbar^2 . It follows that α is an eigenvalue of the operator \mathbf{H} with order accuracy \hbar^2 .

Indeed, assuming that d is the distance from α to the spectrum of the operator \mathbf{H} , $\| \cdot \|$ is the norm in L^2 , and $R_\alpha = (\alpha E - H)^{-1}$ is resolvent \mathbf{H} , we obtain for $\psi =$

$\varphi_0(x) e^{\frac{i}{\hbar} \bar{S}(x)}$ in virtue of (25)

$$\frac{1}{d} = \|R_\alpha\| \geq \frac{\|R_\alpha(\alpha E - H)\psi\|}{\|(\alpha E - H)\psi\|} = \frac{\|\psi\|}{\|(\alpha E - H)\psi\|} \geq \frac{1}{B\hbar^2},$$

where $B > 0$, whence $d \leq B \hbar^2$ and then the lemma follows from the Weyl criterion, QED.

Proposition 2. For Schrödinger equation (9) with a quasiperiodic potential $U(x)$ for all sufficiently small \hbar in the scattering region, the spectrum is continuous for all $\varepsilon, \lambda > 0$. In the region of vibrational motions

1. the spectrum is discrete if λ is rational.
2. If λ is irrational, then the point spectrum with increasing ε monotonically expands to its closure – small segments around the original (at $\varepsilon = 0$) eigenvalues and for ε of order \hbar occupies this entire region. With a further increase in ε to an order of $1/\hbar$, such a picture of the spectrum is preserved, only the region of vibrational motions expands ultimately to the entire space. For ε of order $1/\hbar$, with increasing ε , the point spectrum monotonously narrows to segments converging to discrete points.

Proof. At $\varepsilon = 0$, the potential $U(x) = \cos x$ is periodic. In this case, in the region $|\mathbf{H}(\gamma)| \leq 1$ of the phase space of the dynamical system (6) (in the region of vibrational

motions), the trajectories γ are closed. By virtue of Lemma 2, the spectrum in this region is discrete, and its points with an accuracy of the order of h^2 are equal to the energy values $H(\gamma)$ on such trajectories γ for which condition (13) is satisfied. In the region $|H(\gamma)| > 1$ (the scattering region), the trajectories γ are unbounded and un-closed, so the spectrum here is continuous and, with accuracy of the order of h^2 , is equal to the energy $H(\gamma)$ on the trajectories from this region. For the scattering region, this will always be true with increasing ε .

As ε increases from zero, the periodicity of the potential $U(x)$ disappears, on the interval $[2\pi k; 2\pi(k+1)]$ it has the form

$$U(x) = \cos(x) + \varepsilon \cos(2\pi k\lambda + \lambda x) \quad (x \in [0; 2\pi]). \quad (26)$$

If λ is rational and $\lambda = \frac{p}{q}$, then there are no more than q different such potentials

and for each of them the spectrum is discrete. For irrational λ , the points $2\pi k\lambda$ modulo 2π everywhere densely fill the segment $[0; 2\pi]$ and their closure coincides with the segment.

Consider on the segment $[0; 2\pi]$ dynamic system (6) with potential $\bar{U}(x) = \cos(x) + \cos(\mu + x)$, smooth in the parameters $\varepsilon \geq 0$ and $\mu \in [0; 2\pi]$, For $\mu = 2\pi k\lambda \pmod{2\pi}$ for the potential \bar{U} ρ -length $I = I(H, \varepsilon, \mu)$ of closed trajectory with given energy H and $\varepsilon > 0$ is equal to ρ -length trajectories for the initial potential U (26) with the same H and ε on the interval $[2\pi k; 2\pi(k+1)]$.

As for potential \bar{U} $\frac{dI(H, \varepsilon, \mu)}{dH} > 0$ at $\varepsilon = 0$, then this is also true for suffi-

ciently small $\varepsilon > 0$. Let the inverse function $f(I) = f(I, \mu, \varepsilon)$ associates the ρ -length I of a closed trajectory with its energy level H . According to Lemma 2, for $I = h(n + \frac{1}{2})$ ($n = 0, 1, \dots$) all this $H = f(I, \mu, \varepsilon)$ and there only are the eigenvalues (4)

with order of accuracy h^2 . Since the dependence of f on μ is continuous, then for fixed I and $\varepsilon > 0$ image of the segment $[0; 2\pi]$ along the μ axis is some segment K_I along the H axis.

The length of the segment K_I smoothly depends on ε , and for sufficiently small h and ε of order h it increases approximately linearly with increasing ε . Therefore, with increasing ε , the union of the segments K_I over all $I = h(n + \frac{1}{2})$ ($n = 0, 1, \dots$) will

cover all values of energy in the field of oscillatory movements.

All the above considerations remain valid with a further increase in ε , and therefore the spectral picture does not change, only the range of vibrational motions expands. As $\varepsilon \rightarrow \infty$, this region occupies the entire phase space. Moreover, in the spectral pattern in this region, a process occurs that is opposite to what was when ε changed from zero to h . Namely, the point spectrum narrows to segments converging in the limit to discrete points corresponding to phase curves with ρ -length $I = h(n + \frac{1}{2})$ ($n = 0,$

1, ...) for potential $\cos \lambda x$. This follows from the symmetry of the plots $0 < \varepsilon < h$ and $1/h < \varepsilon < \infty$: divide equation (4) by ε

$$\frac{ih}{\varepsilon} \frac{\partial \psi}{\partial t} = -\frac{h^2}{\varepsilon} \frac{\partial^2 \psi}{\partial x^2} + \left(\frac{1}{\varepsilon} \cos x + \cos \lambda x\right) \psi$$

As a result of the replacement of variables $\tilde{t} = \varepsilon t$, $\tilde{x} = \sqrt{\varepsilon} x$, $\tilde{\varepsilon} = \frac{1}{\varepsilon}$, we obtain

$$ih \frac{\partial \psi}{\partial \tilde{t}} = -h^2 \frac{\partial^2 \psi}{\partial \tilde{x}^2} + (\tilde{\varepsilon} \cos x + \cos \lambda x) \psi$$

At $\varepsilon \rightarrow \infty$, i.e. $\tilde{\varepsilon} \rightarrow 0$ we back to the periodic case with potential $U(x) = \cos \lambda x$, QED.

4 Conclusion

The structural stability of a mathematical model is a necessary condition for its correctness. But after S. Smale's works it became clear that in smooth dynamics the system of a general form is not structurally stable and therefore there is no strict mathematical basis for modeling and computational analysis of systems. The contradiction appeared in science: according to physicists dynamics is simple and universal.

The solution to this problem was proposed based on the construction of dynamic quantum models (DQM). From the assumption that quantum effects are caused by unrecoverable "white noise", a certain mathematical model of quantum mechanics already follows and is essentially unambiguous. This model is simply connected with the traditional one. Construction of such models can be considered as an asymptotic method for solving spectral problems, for example, for the one-dimensional system with the quasiperiodic potential.

But the definition of DQM is not formally related to Hamiltonian systems; it is defined for any ordinary differential equation or any diffeomorphism on any smooth Riemannian manifold. DQM is defined and constructed universally for both Hamiltonian systems and systems with the truth function. As a result, for example, the point of the DQM spectrum is interpreted exactly as the average value of truth from approximate logical conclusions. Quantization with the Bohr-Sommerfeld condition also extends to systems with a truth function.

Hopefully this will allow a new approach to the problems of dynamical systems that using logical operations: algorithms, theorems, software applications.

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Understanding Clock Constraints Coalgebraically

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Abstract. The paper is devoted to the problem specifying causality relationships in distributed (including cyber-physical) systems. This problem is studied based on the coalgebraic approach used authors for studying safety constraints for distributed systems. The special class of coalgebras, counter-based detectors, is introduced and studied in the paper. It is shown that this approach allows using the technique of Diophantine equations for specifying clock constraints of the system being studied. The advantage of the approach is the possibility for defining the complexity of detectors that provides to control respond time of the detectors in the system.

Keywords: a coalgebra, a detector coalgebra, a counter-based detector, Diophantine equation, Clock Constraint Specification Language

1 Introduction

This paper presents the authors' research continuing the research presented in [1] and applying the proposed approach and results in a more specific situation.

The general context of our study is determined by the observation that modern technical systems are, as a rule, compound and smart. Moreover, such systems can be hybrid in the sense that ones consisted of physical, cybernetic (software), and, maybe, social components. This character of the systems should be taken into account under designing ones.

The software components of such systems are reactive, that is, they are designed for providing the required behaviour of the system, and not for obtaining any computational result.

Components of such systems are distributed in space but should act for guaranteeing the required behaviour of the system in the whole. So, supporting the necessary causality relationships during operating of system components is one of the principal problems of designing a system of such a kind.

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Also, we need to remark the incorrect behaviour of a system of the considering kind can have serious and some times catastrophic consequences for the system surroundings. Hence, systems of this class can be characterised as safety-critical systems. Thus, all designing solutions for them should be rigorous verified.

This research is some attempt to build a foundation for rigorous and effective specification and analysis of causality relationships in systems of the considering class.

This paper applies the general framework proposed in [1] for constructing rigorous models of logical time intended for using under developing domain-specific languages for specifying causality constraints.

The paper is structured as follows.

Sec. 2 reminds basic concepts and notation.

Sec. 3 contains the necessary definitions and results for understanding the general coalgebraic framework.

Sec. 4 contains a survey of used below results from [1].

Sec. 5 explains how results mentioned above can be used for specification and analysis causality constraints.

Sec. 6 is the key in the article. Here, it is introduced the concept of a counter-based detector; it is explained that this class of detectors is not complete; it is constructed a Diophantine representation for detectors of this class.

Finally, Sec. 7 presents the construction of a universal simulator based on the Diophantine representation for counter-based detectors.

2 Basic Concepts and Notation

This section is a copy of the corresponding section of our article [1] and here it is presented only for providing notation consistency. Thus, we assume that X is a finite set with at least two elements. Elements of this set are usually interpreted as system notifications.

A mapping (generally speaking partial) $s : \mathbb{N} \rightarrow X$ is called an *X -sequence* if for any $k \in \mathbb{N}$, $s k'$ is defined whenever $s k$ is defined and $0 \leq k' < k$.

An X -sequence s is called an *X -word* if there exists $k \in \mathbb{N}$ such that $s k$ is undefined; in contrast, an X -sequence s is called a *X -stream* if $s k$ is defined for all $k \in \mathbb{N}$.

We use the notation X^* for referring to the set of all X -words, and $X^{\mathbb{N}}$ for referring to the set of all X -streams. The set X^* contains the sequence defined nowhere, which is below denoted by ϵ .

We use also the notation X^∞ for referring to the set $X^* \cup X^{\mathbb{N}}$, and X^+ for referring to the set of all X -words without the word defined nowhere.

For an X -word u , we denote by $|u|$ the minimal natural number such that $u |u|$ is undefined.

The value $|u|$ where $u \in X^*$ is called *length* of u .

As usually, we identify $n \in X$ with the X -word $u \in X^*$ such that $u 0 = n$ and $u k$ is undefined if $k > 0$.

For $\mathbf{u} \in X^*$ and $\mathbf{s} \in X^\infty$, we denote by $\mathbf{u}\mathbf{s}$ the next X -sequence

$$\mathbf{u}\mathbf{s} = \lambda k \in \mathbb{N} . \begin{cases} \mathbf{u}k & \text{if } k < |\mathbf{u}| \\ \mathbf{s}(k - |\mathbf{u}|) & \text{otherwise} \end{cases}$$

Below we need in the following set

$$n^{-1} \cdot A = \{\mathbf{u} \in X^* \mid n\mathbf{u} \in A\} \quad \text{where } A \subset X^* \text{ and } n \in X.$$

For $\mathbf{s} \in X^\infty$ and $m \in \mathbb{N}$, we denote by $\mathbf{s}_{m..}$ the next X -sequence

$$\mathbf{s}_{m..} = \lambda k \in \mathbb{N} . \begin{cases} \mathbf{s}(k + m) & \text{if this value is defined} \\ \text{is undefined} & \text{otherwise} \end{cases}$$

Also for $\mathbf{s} \in X^\infty$ and $m, l \in \mathbb{N}$, we denote by $\mathbf{s}_{m..l}$ the next X -word

$$\mathbf{s}_{m..l} = \lambda k \in \mathbb{N} . \begin{cases} \mathbf{s}(k + m) & \text{if this value is defined and } k < l - m \\ \text{is undefined} & \text{otherwise} \end{cases}$$

The principal concepts for our studying is given by the following definitions

Definition 1. A subset $P \subset X^*$ is called **prefix-free** if $\mathbf{u} \in P$ ensures $\mathbf{u}_{0..m} \notin P$ whenever $0 \leq m < |\mathbf{u}|$.

Remark 1. If a prefix-free subset of X^* contains ϵ then this subset is $\{\epsilon\}$. Indeed, if a prefix-free subset of X^* contains both ϵ and another X -word \mathbf{u} then $\mathbf{u}_{0..0} = \epsilon$ cannot belong to this subset. This contradiction grounds the remark.

Definition 2 (see [2]). A **safety constraint** is a subset $S \subset X^\mathbb{N}$ such that $\mathbf{s} \in S$ if for any $m \in \mathbb{N}$, $\mathbf{s}_{0..m} = \mathbf{s}'_{0..m}$ for some $\mathbf{s}' \in S$.

3 Coalgebras Preliminaries

In this section, we remind the basic definitions and facts related to the concept of a coalgebra in an arbitrary category. In addition, we give some specific concepts in the case when $\mathbb{C} = \mathbf{Set}$.

Thus, we assume the category \mathbb{C} and the endofunctor \mathbf{F} of \mathbb{C} are given and held fixed in this section¹.

Definition 3. A morphism a of \mathbb{C} is called an **\mathbf{F} -coalgebra** if the equation $\text{cod } a = \mathbf{F}(\text{dom } a)$ is fulfilled. In the case, $\text{dom } a$ is called the **carrier** of a and denoted below by \underline{a} .

¹ General information on category theory can be found in [3,4], proofs of some facts formulated in the subsection can be found in [1, Sec. 3]

Definition 4. Let a and b be \mathbf{F} -coalgebras then a morphism $f: \underline{a} \rightarrow \underline{b}$ is called an **\mathbf{F} -morphism** from a into b (symbolically, $f: a \rightarrow b$) if the diagram

$$\begin{array}{ccc} \underline{a} & \xrightarrow{f} & \underline{b} \\ \downarrow a & & \downarrow b \\ \mathbf{F} \underline{a} & \xrightarrow{\mathbf{F} f} & \mathbf{F} \underline{b} \end{array}$$

commutes or, equivalently, the equation $(\mathbf{F} f) a = b f$ holds.

Proposition 1. The class of \mathbf{F} -coalgebras equipped with \mathbf{F} -morphisms is a category denoted usually by $\mathbf{Coalg}_{\mathbf{F}}(\mathbb{C})$ or $\mathbf{Coalg}_{\mathbf{F}}$ if the category \mathbb{C} is clear from the context.

Definition 5.

- (1) A terminal object of $\mathbf{Coalg}_{\mathbf{F}}$ if it exists is called a **final \mathbf{F} -coalgebra**, which is denoted by $\mathbf{v}\mathbf{F}$.
- (2) For any \mathbf{F} -coalgebra a , the unique \mathbf{F} -morphism from a into $\mathbf{v}\mathbf{F}$ is called an **anamorphism** and denoted by $\llbracket a \rrbracket$.

4 Safety Behavioural Constraints

This section contains some survey of the results obtained in [1].

In [1], three endofunctors \mathbb{T} , $\mathbb{S}_{\mathbf{N}}$, and $\mathbb{D}_{\mathbf{N}}$ of category **Set** are considered. Here \mathbf{N} refers to some finite set of system notifications. The definitions of these functors are given in Table 1.

Table 1. Functors \mathbb{T} , $\mathbb{S}_{\mathbf{N}}$, and $\mathbb{D}_{\mathbf{N}}$ definitions

\mathbf{F}	$\mathbf{F} X$ where $X \in \mathbf{Set}$	$\mathbf{F} f$ where $X, Y \in \mathbf{Set}$ and $f: X \rightarrow Y$
\mathbb{T}	$\mathbb{T} X = 1 + X$	$\mathbb{T} f = \lambda x \in \mathbb{T} X . \begin{cases} \Downarrow & \text{if } x = \Downarrow \\ fx & \text{otherwise} \end{cases}$
$\mathbb{S}_{\mathbf{N}}$	$\mathbb{S}_{\mathbf{N}} X = \mathbf{N} \times X$	$\mathbb{S}_{\mathbf{N}} f = \text{id}_{\mathbf{N}} \times f$
$\mathbb{D}_{\mathbf{N}}$	$\mathbb{D}_{\mathbf{N}} X = (1 + X)^{\mathbf{N}}$	$\mathbb{D}_{\mathbf{N}} f = \lambda \phi \in \mathbb{D}_{\mathbf{N}} X . \lambda \mathbf{n} \in \mathbf{N} . \begin{cases} \Downarrow & \text{if } \phi \mathbf{n} = \Downarrow \\ f(\phi \mathbf{n}) & \text{otherwise} \end{cases}$

In Table 1, “+” means disjoint union, $1 = \{\Downarrow\}$ for some \Downarrow , and “ \times ” means Cartesian product.

In the mentioned above paper, any $\mathbb{S}_{\mathbf{N}}$ -system $\sigma: \underline{\sigma} \rightarrow \mathbb{S}_{\mathbf{N}} \underline{\sigma}$ is interpreted as a system with output \mathbf{N} (see [1, Subsec. 4.2]), any $\mathbb{D}_{\mathbf{N}}$ -system $\mathbf{a}: \underline{\mathbf{a}} \rightarrow \mathbb{D}_{\mathbf{N}} \underline{\mathbf{a}}$ is interpreted as a detector of behavioural violations (see [1, Subsec. 4.3]), and

interrelation between systems with output and detectors is established using the bifunctor combining a system and a detector into the system with termination

$$\text{Join} : \mathbf{Sys}(\mathbf{S}_{\mathbf{N}}) \times \mathbf{Sys}(\mathbf{D}_{\mathbf{N}}) \rightarrow \mathbf{Sys}(\mathbf{T})$$

(see [1, Subsec. 5.1]). This bifunctor is defined as follows, let σ and \mathbf{a} be a system with output \mathbf{N} and an \mathbf{N} -detector respectively, one can define the system with termination $\text{Join}(\sigma, \mathbf{a}) : \underline{\sigma} \times \underline{\mathbf{a}} \rightarrow \mathbf{T}(\underline{\sigma} \times \underline{\mathbf{a}})$ by the next rules

$$\text{Join}(\sigma, \mathbf{a}) = \lambda (x, y) \in \underline{\sigma} \times \underline{\mathbf{a}} . \begin{cases} \Downarrow & \text{if } (\mathbf{a}y)(\sigma_{\text{out}} x) = \Downarrow \\ \langle \sigma_{\text{tr}} x, (\mathbf{a}y)(\sigma_{\text{out}} x) \rangle & \text{otherwise} \end{cases} \quad (1a)$$

Further for systems σ and τ with output \mathbf{N} and \mathbf{N} -detectors \mathbf{a} and \mathbf{b} , an $\mathbf{S}_{\mathbf{N}}$ -morphism $f : \sigma \rightarrow \tau$, and a detector morphism $g : \mathbf{a} \rightarrow \mathbf{b}$, we define the mapping $\text{Join}(f, g) : \underline{\sigma} \times \underline{\mathbf{a}} \rightarrow \underline{\tau} \times \underline{\mathbf{b}}$ by the formula

$$\text{Join}(f, g) = f \times g. \quad (1b)$$

Above, we use the representation $\sigma x = \langle \sigma_{\text{out}} x, \sigma_{\text{tr}} x \rangle$.

Further in [1], it is proposed to describe the set of streams accepted by a detector \mathbf{a} as follows

- first of all for $\mathbf{s} \in \mathbf{N}^{\mathbb{N}}$, let us define the following system $[\mathbf{s}]$ with output namely

$$[\mathbf{s}] = \{s_{k..} \mid k \in \mathbb{N}\} \quad \text{and} \quad [\mathbf{s}] = \lambda \mathbf{t} \in [\mathbf{s}] . \langle \mathbf{t}0, \mathbf{t}_{1..} \rangle;$$

- now for any \mathbf{N} -detector \mathbf{a} and $x \in \underline{\mathbf{a}}$, let us define the following set

$$\llbracket \mathbf{a} \rrbracket_x = \{ \mathbf{s} \in \mathbf{N}^{\mathbb{N}} \mid \llbracket \text{Join}([\mathbf{s}], \mathbf{a}) \rrbracket(\mathbf{s}, x) = \infty \}.$$

One of the main results obtained in [1, Lemmas 5 and 6] is established that any safety constraint has the described above form.

Below we use this approach for studying causality constraints in distributed systems.

5 Causality Constraints as a Kind of Safety Behavioural Ones

Anywhere in this section, \mathbf{C} is an arbitrary but fixed finite set of clocks and \mathbf{NC} is the corresponding set of clock notifications that is the set of all non-empty subset of \mathbf{C} . Informally, each message contains a list of clocks had ticked at the same time as the message was sent. Thus, notifications are no longer atomic entities or, in other words, first-class citizens. Now, clock ticks are atomic entities or, in other words, first-class citizens, whose combinations are notifications. In this section, we show how the results obtained in [1] should be adjusted for this more specific situation.

5.1 Clock and Schedules Coalgebraically

The logic clock model considers clock tick notification streams as the only information available about temporal order between events. These streams are called schedules in the model context. Thus, the coalgebraic meaning of schedules is related to the endofunctor $\mathbf{S}_{\mathbf{NC}} : \mathbf{Set} \rightarrow \mathbf{Set}$ defined like to the endofunctor $\mathbf{S}_{\mathbf{N}}$ from [1, Subsec. 4.2] namely

$\mathbf{S}_{\mathbf{NC}} X = \mathbf{NC} \times X$ for any object X of category **Set**;

$\mathbf{S}_{\mathbf{NC}} f = \text{id}_{\mathbf{NC}} \times f$ for any objects X and Y of category **Set** and a morphism $f : X \rightarrow Y$

then a system equipped with the clock set C is an $\mathbf{S}_{\mathbf{NC}}$ -system.

In other words, a system equipped with a clock set C is a mapping $\sigma : X \rightarrow \mathbf{S}_{\mathbf{NC}} X$ that both specifies the state transition $\sigma_{\text{tr}} : X \rightarrow X$ and the corresponding ensemble of clock ticks $\sigma_{\text{out}} : X \rightarrow \mathbf{NC}$ of the system such that $\sigma = \langle \sigma_{\text{out}}, \sigma_{\text{tr}} \rangle$ is a universal arrow from X into $\mathbf{NC} \times X$.

A final $\mathbf{S}_{\mathbf{NC}}$ -system $\mathbf{vS}_{\mathbf{NC}}$ is defined on the set $\mathbf{NC}^{\mathbf{N}}$ of all schedules and has $\lambda s \in \mathbf{NC}^{\mathbf{N}} . s_{1..}$ as the transition function and $\lambda s \in \mathbf{NC}^{\mathbf{N}} . s_0$ as the output function (see, [1, Subsec. 4.2]).

Due to the general results mentioned in [1, Sec. 3 and Subsec. 4.2], our capacity to formulate causality constraints for any system equipped with a clock set C are limited by statements in schedules terms only.

5.2 Detectors of Causality Constraint Violations

Detectors of causality constraint violations are described with using the endofunctor $\mathbf{D}_{\mathbf{NC}} : \mathbf{Set} \rightarrow \mathbf{Set}$ defined like to [1, Sec. 4.3] namely

$\mathbf{D}_{\mathbf{NC}} X = (1 + X)^{\mathbf{NC}}$ for any object X of category **Set**;

$\mathbf{D}_{\mathbf{NC}} f = \lambda \phi \in (1 + X)^{\mathbf{NC}} . \lambda n \in \mathbf{NC} . \begin{cases} \Downarrow & \text{if } \phi n = \Downarrow \\ f(\phi n) & \text{otherwise} \end{cases}$

for any objects X and Y of category **Set** and a morphism $f : X \rightarrow Y$.

Definitions of bifunctor Join , sets of the form $\llbracket \mathbf{a} \rrbracket_x$ where \mathbf{a} is an \mathbf{NC} -detector, and $x \in \underline{\mathbf{a}}$ are remained without changing.

6 Counter-based Detectors and Their Diophantine Representation

In this section, we consider a special class of \mathbf{NC} -detectors². Some detectors of this class are used for defining semantics of Clock Constraint Specification Language (CCSL) [5].

In this section, we use the function $\text{occ}_c : \mathbf{NC}^* \rightarrow \mathbb{N}$ associated with $c \in C$ as follows

$$\text{occ}_c = \lambda u \in \mathbf{NC}^* . \begin{cases} 0 & \text{if } u = \epsilon \\ \text{occ}_c u' & \text{if } u = u'n \text{ for } u' \in \mathbf{NC}^*, n \in \mathbf{NC}, \text{ and } c \notin n \\ \text{occ}_c u' + 1 & \text{if } u = u'n \text{ for } u' \in \mathbf{NC}^*, n \in \mathbf{NC}, \text{ and } c \in n \end{cases}$$

² In this section, C is some clock set

This function counts how many times the corresponding clock ticked if the schedule begin coincides with the function argument.

6.1 Counter-based Detectors

Let $V \subset \mathbf{NC} \times \mathbb{N}^C$ then an \mathbf{NC} -detector \mathbf{c}_V is called a counter-based \mathbf{NC} -detector if it is defined as follows

$$\begin{aligned} \mathbf{c}_V &= \mathbb{N}^C \\ \mathbf{c}_V &= \lambda x \in \mathbb{N}^C . \lambda \mathbf{n} \in \mathbf{NC} . \begin{cases} \Downarrow & \text{if } \langle \mathbf{n}, x \rangle \in V \\ x + \mathbf{n} & \text{otherwise} \end{cases} \end{aligned}$$

where $x + \mathbf{n} = \lambda c \in \mathbb{C} . \begin{cases} (xc) + 1 & \text{if } c \in \mathbf{n} \\ xc & \text{otherwise} \end{cases}$.

Our nearest aim is to establish whether the family of causality constraints recognised by counter-based detectors is a family with a universal detector.

The first step for achieving the claimed aim is given by the next theorem.

Theorem 1. *Let P be a prefix-free subset of \mathbf{NC}^+ then there exists $\mathbf{A} \subset \mathbf{NC} \times \mathbb{N}^C$ such that $\llbracket \mathbf{c}_A \rrbracket x = P$ for some $x \in \mathbf{c}_A$ if and only if P meets the following condition*

$$\begin{aligned} &\text{for any } \mathbf{v} \in \mathbf{NC}^+, \\ &\mathbf{u}'\mathbf{v} \in P \text{ is equivalent to } \mathbf{u}''\mathbf{v} \in P \text{ whenever } \mathbf{u}', \mathbf{u}'' \in \mathbf{NC}^+ \text{ are such} \\ &\text{that} \\ &\mathbf{u}'_{0..m} \notin P \text{ and } \mathbf{u}''_{0..k} \notin P \text{ for all } 0 < m \leq |\mathbf{u}'|, 0 < k \leq |\mathbf{u}''| \text{ and} \\ &\text{occ}_c \mathbf{u}' = \text{occ}_c \mathbf{u}'' \text{ for each } c \in \mathbb{C}. \end{aligned} \quad (2)$$

For proving the theorem, we need some auxiliary results.

Lemma 1. *For any $V \subset \mathbf{NC} \times \mathbb{N}^C$ and $x \in \mathbf{c}_V$, $\llbracket \mathbf{c}_V \rrbracket x$ meets condition (2).*

Proof. Let us assume $P = \llbracket \mathbf{c}_V \rrbracket x$ for some $V \subset \mathbf{NC} \times \mathbb{N}^C$ and $x \in \mathbf{c}_V$ and take $\mathbf{u}', \mathbf{u}'' \in \mathbf{NC}^+$ such that $\mathbf{u}'_{0..m} \notin P$ and $\mathbf{u}''_{0..k} \notin P$ for all $0 < m \leq |\mathbf{u}'|$, $0 < k \leq |\mathbf{u}''|$ and $\text{occ}_c \mathbf{u}' = \text{occ}_c \mathbf{u}''$ for each $c \in \mathbb{C}$.

Then the first group of conditions ensures $\mathbf{c}_V^+(x, \mathbf{u}'), \mathbf{c}_V^+(x, \mathbf{u}'') \in \mathbf{c}_V$ and the condition $\text{occ}_c \mathbf{u}' = \text{occ}_c \mathbf{u}''$ for each $c \in \mathbb{C}$ ensures $\mathbf{c}_V^+(x, \mathbf{u}') = \mathbf{c}_V^+(x, \mathbf{u}'')$.

Now, for an arbitrary $\mathbf{v} \in \mathbf{NC}^+$ and $0 < k \leq |\mathbf{v}|$, we have (see [1, Lemma 1])

$$\begin{aligned} \mathbf{c}_V^+(x, \mathbf{u}'\mathbf{v}_{0..k}) &= \mathbf{c}_V^+(\mathbf{c}_V^+(x, \mathbf{u}'), \mathbf{v}_{0..k}) \\ &= \mathbf{c}_V^+(\mathbf{c}_V^+(x, \mathbf{u}''), \mathbf{v}_{0..k}) = \mathbf{c}_V^+(x, \mathbf{u}''\mathbf{v}_{0..k}) \end{aligned}$$

Thus, one can conclude $\mathbf{u}'\mathbf{v} \in P$ is equivalent to $\mathbf{u}''\mathbf{v} \in P$.

Proof (Proof of Theorem 1). Taking into account Lemma 1, we need only to prove that for any prefix-free $P \subset \mathbf{NC}$ satisfying condition (2), there exists

$V \subset \mathbf{NC} \times \mathbb{N}^{\mathbb{C}}$ such that $P = \llbracket \mathbf{c}_V \rrbracket x$ for some $x \in \underline{\mathbf{c}}_V$.
To do this let us take

$$V = \{ \langle \mathbf{n}, x \rangle \in \mathbf{NC} \times \mathbb{N}^{\mathbb{C}} \mid \\ \mathbf{v}\mathbf{n} \in P \text{ for some } \mathbf{v} \in \mathbf{NC}^* \text{ such that } x = \lambda c \in \mathbb{C} . \text{occ}_c \mathbf{v} \}$$

and check that $\llbracket \mathbf{c}_V \rrbracket z = P$ where $z = \lambda c \in \mathbb{C} . 0$ i.e. that for any $\mathbf{u} \in \mathbf{NC}^+$, $\mathbf{u} \in \llbracket \mathbf{c}_V \rrbracket z$ iff $\mathbf{u} \in P$.

Let us assume that $\mathbf{u} \in \llbracket \mathbf{c}_V \rrbracket z$.

If $\mathbf{u} = \mathbf{n}$ for some $\mathbf{n} \in \mathbf{NC}$ then $\mathbf{n} \in \llbracket \mathbf{c}_V \rrbracket z$ means $(\mathbf{c}_V z) \mathbf{n} = \Downarrow$ i.e. $\mathbf{n} \in P$ because of $\lambda c \in \mathbb{C} . \text{occ}_c \mathbf{v} = z$ iff $\mathbf{v} = \epsilon$.

If $\mathbf{u} \in \llbracket \mathbf{c}_V \rrbracket z$ and $m = |\mathbf{u}| > 1$ then for $x_0 = z$, we have $x_{k+1} = (\mathbf{c}_V x_k)(\mathbf{u}k) \in \underline{\mathbf{c}}_V$ whenever $k = 0, \dots, m-2$ and $(\mathbf{c}_V x_{m-1})(\mathbf{u}(m-1)) = \Downarrow$. In other words, $\langle \mathbf{u}k, x_k \rangle \notin V$ where $k = 0, \dots, m-2$ and $\langle \mathbf{u}(m-1), x_{m-1} \rangle \in V$.

Thus, $\mathbf{u}_{0..k} \notin P$ for any $0 < k \leq m-1$ but there exists $\mathbf{v} \in \mathbf{NC}^*$ such that $\mathbf{v}\mathbf{u}(m-1) \in P$ and $\lambda c \in \mathbb{C} . \text{occ}_c \mathbf{v} = \lambda c \in \mathbb{C} . \text{occ}_c \mathbf{u}_{0..m-1}$. But the condition $\mathbf{v}\mathbf{u}(m-1) \in P$ implies $\mathbf{v}_{0..l} \notin P$ for any $0 < l \leq |\mathbf{v}|$ due to P is a prefix free set. Thus, condition (2) ensures $\mathbf{u} = \mathbf{u}_{0..m-1}(\mathbf{u}(m-1)) \in P$.

Now assume $\mathbf{u} \in P$ and $m = |\mathbf{u}|$.

Then we have $\mathbf{u}_{0..k} \notin P$ for any k such that $0 < k < m$ and $\langle \mathbf{u}(m-1), \lambda c \in \mathbb{C} . \text{occ}_c \mathbf{u}_{0..m-1} \rangle \in V$ due to the definition of V . One can conclude that $\langle \mathbf{u}k, \lambda c \in \mathbb{C} . \text{occ}_c \mathbf{u}_{0..k} \rangle \notin V$ for any $0 \leq k < m-1$. Indeed, otherwise there exists $0 \leq k < m-1$ and $\mathbf{v} \in \mathbf{NC}^*$ such that $\mathbf{v}(\mathbf{u}k) \in P$ and $\lambda c \in \mathbb{C} . \text{occ}_c \mathbf{v} = \lambda c \in \mathbb{C} . \text{occ}_c \mathbf{u}_{0..k}$. But condition (2) ensures $\mathbf{u}_{0..k}(\mathbf{u}k) = \mathbf{u}_{0..k+1} \in P$ for some $0 \leq k < m-1$. Thus $\mathbf{c}_V^+(z, \mathbf{u}_{0..k}) \in \underline{\mathbf{c}}_V$ for $0 < k < m$ and $\mathbf{c}_V^+(z, \mathbf{u}) = \Downarrow$. Therefore we have $\mathbf{u} \in \llbracket \mathbf{c}_V \rrbracket z$.

Corollary 1. *If $P = \llbracket \mathbf{c}_V \rrbracket x$ for some $V \subset \mathbf{NC} \times \mathbb{N}^{\mathbb{C}}$ and $x \in \underline{\mathbf{c}}_V$ then $P = \llbracket \mathbf{c}_{V'} \rrbracket z$ for some $V' \subset \mathbf{NC} \times \mathbb{N}^{\mathbb{C}}$ and $z = \lambda c \in \mathbb{C} . 0$.*

Corollary 2. *The family of clock constraints being detected by counter-based detectors is a constraint family with a universal detector.*

Proof. To prove this fact, we use [1, Theorem 5]. Assume $P = \llbracket \mathbf{c}_V \rrbracket z$ for some $V \subset \mathbf{NC} \times \mathbb{N}^{\mathbb{C}}$.

Let $\mathbf{n} \notin P$, $\mathbf{u}'_{0..m}, \mathbf{u}''_{0..k} \notin \mathbf{n}^{-1} \cdot P$ for all $0 < m \leq |\mathbf{u}'|$ and $0 < k \leq |\mathbf{u}''|$, and $\text{occ}_c \mathbf{u}' = \text{occ}_c \mathbf{u}''$ for any $c \in \mathbb{C}$ then $\mathbf{n}\mathbf{u}'_{0..m} \notin P$ and $\mathbf{n}\mathbf{u}''_{0..k} \notin P$. Theorem 1 ensures $(\mathbf{n}\mathbf{u}')\mathbf{v} \in P$ and $(\mathbf{n}\mathbf{u}'')\mathbf{v} \in P$ are equivalent for any $\mathbf{v} \in \mathbf{NC}^+$ i.e. $\mathbf{u}'\mathbf{v} \in \mathbf{n}^{-1} \cdot P$ and $\mathbf{u}''\mathbf{v} \in \mathbf{n}^{-1} \cdot P$ are equivalent.

Theorem 1 allows us to show the impossibility of confining ourselves to counters based detectors, as shown in the next example and the remark following after it.

Example 1. Let us take $\mathbf{C} = \{c_1^+, c_1^-, \dots, c_m^+, c_m^-\}$ for some $m > 1$ and define the next NC-detector \mathfrak{q}

$$\mathfrak{q} = \{c_1, \dots, c_m\}^*$$

$$\mathfrak{q} = \lambda \mathbf{u} \in \{c_1, \dots, c_m\}^* . \lambda \mathbf{n} \in \mathbf{NC} . \begin{cases} \mathbf{u}\{c_k\} & \text{if } \mathbf{n} = \{c_k^+\} \\ & \text{for some } k = 1, \dots, m \\ \mathbf{u}' & \text{if } \mathbf{u} = \{c_k\}\mathbf{u}' \text{ and } \mathbf{n} = \{c_k^-\} \\ & \text{for some } k = 1, \dots, m \\ \Downarrow & \text{otherwise} \end{cases}$$

Also, let us take $P = \llbracket \mathfrak{q} \rrbracket \epsilon$, and $\{c_i^+\}\{c_j^+\}, \{c_j^+\}\{c_i^+\} \in \mathbf{NC}^+$ for any $1 \leq i \neq j \leq m$. Then it is evident $\mathfrak{q}^+(\epsilon, \{c_i^+\}\{c_j^+\}) \neq \Downarrow$, $\mathfrak{q}^+(\epsilon, \{c_j^+\}\{c_i^+\}) \neq \Downarrow$, and $\text{occ}_{c_k^\pm} \{c_i^+\}\{c_j^+\} = \text{occ}_{c_k^\pm} \{c_j^+\}\{c_i^+\}$ for all $k = 1, \dots, m$. In other words, $\{c_i^+\} \notin P$, $\{c_i^+\}\{c_j^+\} \notin P$, $\{c_j^+\} \notin P$, $\{c_j^+\}\{c_i^+\} \notin P$, and $\text{occ}_{c_k^\pm} \{c_i^+\}\{c_j^+\} = \text{occ}_{c_k^\pm} \{c_j^+\}\{c_i^+\}$ for all $k = 1, \dots, m$.

The assumption $P = \llbracket \mathfrak{c}_V \rrbracket x$ for some $V \subset \mathbf{NC} \times \mathbb{N}^{\mathbf{C}}$ and $x \in \underline{\mathfrak{c}_V}$ leads to the equivalence of the statements $\{c_i^+\}\{c_j^+\}\{c_i^-\} \in P$ and $\{c_j^+\}\{c_i^+\}\{c_i^-\} \in P$ due to Lemma 1.

But the definition of \mathfrak{q} ensures $\{c_i^+\}\{c_j^+\}\{c_i^-\} \notin P$ and $\{c_j^+\}\{c_i^+\}\{c_i^-\} \in P$. This contradiction proofs that for any $V \subset \mathbf{NC} \times \mathbb{N}^{\mathbf{C}}$ and $x \in \underline{\mathfrak{c}_V}$, $P = \llbracket \mathfrak{c}_V \rrbracket x$ is false.

Remark 2. This abstract example has practical value. Indeed, let we have $m(m > 1)$ servers each of them provides access to the queue being stored by it. Then c_k^+ and c_k^- can be interpreted as append and pop operations respectively for the k^{th} queue.

Example 1 guarantees the behaviour like to a queue behaviour for the system of the servers cannot be ensured by a counter-based detector.

Remark 3. Reasoning similar to the reasoning given in Example 1 leads to the conclusion that the behaviour like to a stack for the system of the servers cannot be ensured by a counter-based detector.

6.2 Diophantine Representation of a Counter-Based Detector

The definition of a counter-based detector ensures that such a detector \mathfrak{c}_V is uniquely defined by the corresponding set $V \subset \mathbf{NC} \times \mathbb{N}^{\mathbf{C}}$, which below is referred as the *defining set* of a counter-based detector. Hence, to specify \mathfrak{c}_V we need to specify V . Taking into account that any tool for specifying a set can specify a recursively enumerable set only, we concentrate on counter-based detectors with the recursively enumerable determining set. Such a counter-based detector is below called a *recursively defined counter-based detector*. Everywhere below we consider counter-based detectors with the recursively enumerable defining set only.

Note that a set $V \subset \mathbf{NC} \times \mathbb{N}^{\mathbf{C}}$ is recursively enumerable if and only if the sets $V_{\mathbf{n}} = \{x \in \mathbb{N}^{\mathbf{C}} \mid \langle \mathbf{n}, x \rangle \in V\}$ are recursively enumerable for all $\mathbf{n} \in \mathbf{NC}$.

This claim follows directly from the finiteness of \mathbf{NC} . In other words, to specify a recursively enumerable set $V \subset \mathbf{NC} \times \mathbb{N}^C$ is equivalent to specify the set $\{V_{\mathbf{n}} \mid \mathbf{n} \in \mathbf{NC}\}$ of recursively enumerable subsets of \mathbb{N}^C .

Due to Matiyasevich-Davis-Robinson-Putnam theorem (see, [6]), the last is equivalent to specifying for any $\mathbf{n} \in \mathbf{NC}$ a polynomial $P_{\mathbf{n}}$ such that

$$V_{\mathbf{n}} = \{x \in \mathbb{N}^C \mid P_{\mathbf{n}}(x, y_1, \dots, y_s) = 0 \text{ for some } y_1, \dots, y_s \in \mathbb{N}\}.$$

Thus, any family of the species $\{P_{\mathbf{n}} \in \mathbb{Z}[x_1, \dots, x_m, y_1, \dots, y_s] \mid \mathbf{n} \in \mathbf{NC}\}$ where m is the cardinal number of C and s is some positive natural number specifies the set $V \subset \mathbf{NC} \times \mathbb{N}^C$ as follows

- (1) let us select some enumeration $\{c_1, \dots, c_m\}$ of clocks from C ;
- (2) let us associate natural variable x_i with clock c_i ($1 \leq i \leq m$);
- (3) for each $\mathbf{n} \in \mathbf{NC}$, let us specify polynomials $P_{\mathbf{n}} \in \mathbb{Z}[x_1, \dots, x_m, y_1, \dots, y_s]$;
- (4) let us assume

$$\langle \mathbf{n}, x \rangle \in V \quad \text{iff} \quad \exists y_1 \in \mathbb{N}; \dots; y_s \in \mathbb{N}, P_{\mathbf{n}}(x, y_1, \dots, y_s) = 0.$$

Below we refer to this manner of specifying the defining set of a counter-based detector as to a **Diophantine Representation** of the detector.

Example 2 (of a Diophantine Representation). Let us assume $C = \{c_1, c_2\}$ and consider the clock constraints specification defined as in Table 2. This specifica-

Table 2. An example of a Diophantine Representation

c_1	c_2	$P(x_1, x_2, y_1)$	Diophantine set
0	1	$x_1 - x_2 + y_1$	$\{(x_1, x_2) \in \mathbb{N}^2 \mid x_1 \leq x_2\}$
1	0	$1 + x_1 - x_2 + y_1$	$\{(x_1, x_2) \in \mathbb{N}^2 \mid x_1 < x_2\}$
1	1	$x_1 - x_2 + y_1$	$\{(x_1, x_2) \in \mathbb{N}^2 \mid x_1 \leq x_2\}$

tion determines that clock c_1 is strictly faster than clock c_2 and can be considered as a specification of the Lamport's relation "happen before" (see [7]).

Note that the rows corresponding to the situation c_1 does not tick but c_2 ticks and also to the situation c_1 and c_2 tick at the same time are coincide in columns 3 and 4. Hence, we can represent Table 2 as follows

$$\begin{aligned} c_2 &\Rightarrow x_1 - x_2 + y_1 = 0 \\ c_1 \wedge \neg c_2 &\Rightarrow 1 + x_1 - x_2 + y_1 = 0 \end{aligned}$$

7 Universal Diophantine Simulator of Recursive Counter-Based Detectors

In this section, we use Diophantine Representation for describing a universal algorithm simulating any counter-based detector if its defining set is recursive.

The main advantage of this result is that it gives a metric for estimating the complexity of the detector and the detection problem. Namely, the number of additional variables and the power of the polynomial representing the corresponding Diophantine set can be used for defining such a metric. The detailed discussion of this problem one can find in [8].

Let us assume the the universal Diophantine simulator is set up for simulating the counter-based detector with the defining set specified by polynomials $\{P_{\mathbf{n}}(x_1, \dots, x_m, y_1, \dots, y_s) \mid \mathbf{n} \in \mathbf{NC}\}$ under assumption that the clock set is enumerated as follows $C = \{c_1, \dots, c_m\}$. Also, we choose some algorithm α enumerating the set \mathbb{N}^s without repetitions. We mean below that αi is the i -th member of this enumeration.

We begin describing the universal Diophantine simulator of recursive counter-based detectors with specifying its composite structure (see Fig. 1). The simula-

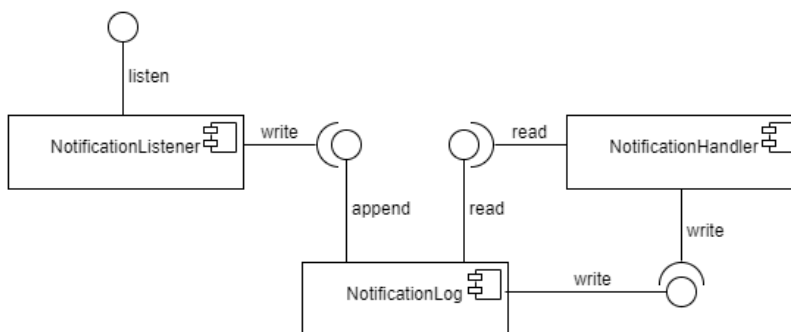


Fig.1. Composite structure of the universal Diophantine simulator of recursive counter-based detectors

tor consists of one passive component (`NotificationLog`) and two active ones (`NotificationListener` and `NotificationHandler`).

Component `NotificationLog` is a data store that allows to write data items in append and direct access modes and to read ones in direct access mode.

Component `NotificationListener` provides listening the notifications channel and writing the corresponding data items using the interface of component `NotificationLog` in accordance with the next algorithm.

`NotificationListener`:

- (1) $x_k \leftarrow 0$ for $k = 1, \dots, m$
- (2) **wait on** receiving a notification
- (3) **let** the received notification be \mathbf{n} **then** append to `NotificationLog` the item $(x_1, \dots, x_m, \mathbf{n}, 0)$
- (4) $x_k \leftarrow x_k + 1$ for $k = 1, \dots, m$ such that $c_k \in \mathbf{n}$
- (5) **go to** (2)

Component `NotificationHandler` provides handling data items stored with `NotificationLog` for recognising behaviour violation in accordance with the following algorithm.

`NotificationHandler`:

- (1) $i \leftarrow 0$
- (2) $j \leftarrow 0$
- (3) **try** to read j -th element from `NotificationLog`
- (4) **if** the attempt is successful **then**
- (5) **let** $(x_1, \dots, x_m, \mathbf{n}, t)$ be the reading result
- (6) $(y_1, \dots, y_s) \leftarrow \alpha t$
- (7) **if** $P_{\mathbf{n}}(x_1, \dots, x_m, y_1, \dots, y_s) = 0$ **then**
 signal about the recognised violation and **terminate** the handling
- (8) rewrite $(x_1, \dots, x_m, \mathbf{n}, t + 1)$ at j -th entry of `NotificationLog`
- (9) $j \leftarrow j + 1$
- (10) **if** $j > i$ **then** $i \leftarrow i + 1$ and $j \leftarrow 0$
- (11) **go to** (3)
- (12) **else go to** (2)

Of course, the proposed universal Diophantine detector is not efficient. For providing efficiency a detector, we need to require the decidability of Diophantine problems related to the detector. For example, we can consider detectors with linear in y_1, \dots, y_s the related to them Diophantine problems. In this case, the complexity of a detector is determined by the complexity of generalized Euclid's algorithm finding the greatest common divisor of coefficients for the corresponding polynomials. Perhaps, other classes of decidable Diophantine problems give also detectors with the controllable complexity.

8 Conclusion

Summing up the mentioned above we can conclude that idea to use the coalgebraic approach for studying logical time in distributed systems gives some interesting results.

First of all, we see that the coalgebraic technique developed in [1] can be used in this more special case. Of course, in this case, we have a possibility enriching the model by using the specific structure of a notification set. It gives us to introduce a mechanism of counting clock ticks and to use values of the corresponding counters for formulating behavioural constraints.

Unfortunately, such an arithmetization does not provide specifying all reasonable causality constraints as it is demonstrated by Example 1 and Remark 3. But it provides a possibility to use a concept of Diophantine complexity [8] for classifying causality constraints of such a kind in accordance with the efficiency of detecting algorithms.

We need to note that assessing the efficiency of detecting algorithms requires answers the following questions

- How to build new detectors from simpler ones?
- Do such constructions possess the universality property?

- Can assess the complexity of the constructed detectors based on the complexity of their components?

These questions define the directions of our future research.

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Platform for Modeling of Algebraic Behavior: Experience and Conclusions

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Abstract. In the article the platform for modeling of algebraic behavior is considered. It is intent for formalization of the systems, especially distributed, their modelling and analysis of the properties. Platform is used for the formal verification, model-based testing and security issues detection. Behavior algebra specifications are used as the modeling language. The number of projects is considered in the paper implemented on platform in cybersecurity, blockchain solutions and legal requirements processing.

Keywords: insertion modeling, formal verification, algebraic behavior, symbolic modeling, formalization.

1 Introduction

The current stage of development of the software systems industry is characterized by a significant complication of the process of their development. Today are widely used cyber-physical systems, blockchain technologies, and, in particular, smart contracts, Distributed ledger technology (DLT), etc.

Cyber-Physical Systems (CPS) are used in space research, transport management, in the energy sector, in production management, in the military sphere, in medicine, in the construction of modern infrastructure, for contactless control of consumer electronics, etc. Typically, CPS are the systems with critical application area. Therefore, when designing such systems, increased demands are placed on their reliability and safety [1].

Distributed ledger technology is information storage technology, the key features of which are the sharing and synchronization of digital data according to the consensus algorithm, the geographical distribution of equivalent copies at different points around the world, the absence of a central administrator [2]. Accordingly, like as any new technology, blockchain has its own vulnerabilities. Thus, all algorithms that are used require the careful analysis and verification, namely, the checking the stability of the system against various attacks, such as Double spending attacks, Grinding attacks,

Transaction denial attacks, Desynchronization attacks, 51% attacks, Selfish-mining, etc.

At the same time, the existing methods of quality control of the developed systems are characterized by incompleteness, high complexity and insufficient reliability. This situation inevitably entails an increase in the number of errors in the development of systems.

As a rule, an analysis of the compliance of a system with the requirements that are imposed on it is carried out either by means of its visual analysis or by a testing method. However, if any of the properties of the system can be formally expressed, for example, in the form of a formula of mathematical logic, then the analysis of this property can be carried out by verification methods.

As a rule, verification is used to analyze the first requirement to the system - its correctness. Note, that this requirement is the main one.

In the first section of this article, a brief description of the current state of theoretical studies in the field of verification and short overview of developed systems for model verification is given. In second section of this article our approach to verification and model testing is presented. The third section of this article describes the Main capabilities and functionality of the platform. In the fourth section a short description of few examples of implemented models is given.

2 Related Works

The problems of modeling and verification of software systems occupy a central position in research on the mathematical theory of programming. This is primarily due to the high relevance of creating a theoretical foundation for the development of reliable software.

In [3-4], the current state of theoretical studies in the field of CPS and their applications in practice is described. The prospects and significance of this direction are justified by the development of roadmaps for the development of this field of research in the USA [5] and in Europe [6].

Since 1970, more than 25 research projects on the use of information technology in legal activity have been developed. The problem of using information technology to legal regulation is not new to the EU, so there are legal policy modeling systems in the EU: EUROMOD, SYSIFF and POLIMOD. In Finland and the Netherlands, JURIX was created by the organization of researchers in the field of law and informatics, who are engaged in computer analysis of legal texts and documents. Thus, article [7] is focused on the method that was developed to model the legislation. The basis for modeling the regulatory framework is UML/OCL. Article [8] presents experience in the analysis of Luxembourg regulatory framework. The idea is also to use a UML approach to model procedural rules. Generally, the model is based on the Domain-Specific Modeling (DSM) approach.

In [9], is also used by UML Activity Diagrams for legal rule formation. After that when models are generated, the resulting model is automatically translated into a

model with using OCL expressions. The resulting OCL legal model can be used for automatic analysis by OCL solvers [9].

Over the past five years found a place the Semantic Web technology and using of ontologies theory in jurisprudence. Thus, tools based on the Semantic Web and ontology theory are generally intended not only to optimize the search for legal information, but also as a tool for clustering, classifying and managing legal knowledge [10].

The paper [11] discusses the approach to constructing agent economic models with using of finite state machines. The authors of this article note, that this approach can be used to model the markets for absolute and monopolistic competition. The article discusses the use of finite state machines for specification and simulation of the Walras model.

The article [12] presents a framework for the analysis and formal verification of Ethereum smart contracts using F* (functional programming language designed to test programs).

There are various technologies of requirements verification. You can use the traditional method of model checking (model checking) or use deductive methods of symbolic modeling (symbolic modeling) with using an automatic proofing and specialized programs such as provers and solvers.

There are many of tools for simulation modeling of behavior in different domains, such as Maple, MatLab, Powersim, Ithink, Arena for economic modeling, SmartCheck, EtherTrust, ZEUS for smart-contracts, EUROMOD, SYSIFF and POLIMOD for jurisprudence, etc.

All systems are popular and can be used in various scientific fields. But the rapid pace of information technology development, and, in turn, the increasing complexity of software, requires to finding new approaches and solutions. That is why we are working to improve formalization technologies. We use algebraic methods to solve problems more precisely and use more expressive languages.

The study is a continuation of the previous authors works in which were presented using methods of algebraic programming and insertion modeling for verification and simulation of crypto-economics, legal, economics models, hardware systems.

At the articles [13-15] considers the formal methods approach for token economy modeling, analysis and studying of its properties. It uses an insertion modelling technique for verification of token economy and behavior algebra specifications for formalization. The project SKILLONOMY is considered as an example of algebraic approach application. The formalization and properties analysis is considered with usage of insertion modeling platform.

In the paper [16] we present the technology and system where algebraic approach demonstrates formal proving of correctness or irregularity of tax actions for tax payers correspondingly to the law. Given example from practice of taxation illustrates findings in Tax Code and inconsistencies of decisions of Taxation Office. Algebraic Programming System is used for detection of such collisions and proving of incorrectness by automatic reasoning from formalized legal requirements.

An example of describing CPS in the IMS system is presented in [17]. The ways of using algebraic interaction theory and insertion modeling technology to solve problems of analysis and synthesis of cyber-physical systems are shown in the article.

In the papers [18-20] overviews the main concepts of insertion modeling, presents new algorithms developed for symbolic verification, especially a new predicate transformer for local descriptions, and provides a formal description of the method of generating traces from such specifications (which is the key technology used to verify requirements and derive test suites).

3 Verification and Model Testing. Our Approach

Model verification is to investigate the behavioral properties of safety or viability. To prove the reachability of the properties, that are checked, can be used the following formal methods of behavior algebra:

- Static - methods for which it is sufficient to prove the feasibility property that is given by the formula in the base language. In other words, there are some values of formula attributes where the formula can be true. Proof of the property of feasibility is achieved by the using of solving machines such as Microsoft Z3 and cvc4.
- Dynamic - Applied to behavioral properties (properties where the formula is represented by expressions of behavior algebra and by semantics of actions, where the formula is represented as an expression in the base language) [21].
- Combined - methods for which the proving of feasibility of formulas is not enough, and it is necessary to prove the reachability of the formula by symbolic modeling.
- Partially dynamic - use the technique of invariants generating [22] in behavior algebra.

A model in the form of algebra of behavior and the property formula, that is verified, are inputs to the verification procedure, and verdict that confirms its reach and a scenario that leading to the corresponding state is its output.

Within the framework of behavior algebra uses such basic verification methods as incompatibility (nondeterminism), incompleteness (deadlocks), compatibility of timing properties, and synchronization problems, critical states (expressing a state of "starvation" when all agents are waiting for receiving of signals, a state of violation of restrictions or other security properties that can be specified by the user), signals racing (when different signal sequences create different states of the environment), properties of liveness, that expressing the reachability of the desired state.

Model testing. To create a test set in a suitable testing environment, an algebraic model can serve as a model for traces generating. At each of the development phases can be checked model artifacts. Both design specifications and binary code can be tested. Direct and inverse symbol modeling are the main methods of test generation.

Necessary covering of code lines by tests is determined by both the requirements for the generation of tests and the model where exhaustive testing can be considered, namely, the generation of all possible states of model behavior, coverage of actions in a model, or coverage of all transitions between actions.

The test is the sequence of reception and sending signals between agents. When performing tests, there are two instances - instance that tests and instance that being tested. Test signals are sent to tests instance and then performed a comparison with the expected result.

The following types of testing are considered when using behavior algebra:

- black box method - a set of tests where the code of the instance that being tested is unknown;
- white box method. The process is determined by the symbolic execution of the parallel composition of model and code. When execution, the states of the environment are compared on equivalence.

4 Main Capabilities and Functionality of the Platform.

4.1 Main Components

The platform consists of the following components:

1. Algebraic Programming System (APS)

APS was developed by the Glushkov Institute of Cybernetics of the National Academy of Science of Ukraine. It was the first system of term rewriting which used the systems of rewriting rules and rewriting strategies separately [23]. The main goal of APS is to create an algebraic program that solves mathematical problems. APS include Proving and Solving Systems.

A Proving System give us a possibilities to prove some trueness of a formula in a theory if the axioms and relation are given. For the resolving equations in Solving Systems in APS are implemented the following theories: enumerated types theory, Boolean logic, linear arithmetic, float arithmetic, string solving, and etc.

2. Insertion Modelling System (IMS)

Insertion Modelling System is an environment for the development of insertion machines, used to represent insertion models of distributed systems [24]. IMS is an extension of APS.

Insertion modeling focuses on building of models and studying the interaction of agents and environments in complex distributed multi-agent systems. The main notion of IMS is the insertion function, which defines the behaviors of agents and actions of environments. We used the behavior algebra specifications for the formalization for the insertion modeling method [25] and the deductive or symbolic method in IMS based on the such external provers and solvers, as Presburger – omega, Fourier-Motzkin - reallib (our tool), cvc3, z3 and MathSAT.

3. Algebraic Engine

An Algebraic Engine is an algebraic tool for modeling of system behavior. It is created on the basis of the IMS system.

It has the following features:

- Generation of symbolic behavior scenarios;
- Resolve the problem of reachability of some property (safety, liveness, and security violations). It detects the reachability of a property given as a formula and given as a behavior in a behavioral algebraic expression;
- Provide verification by symbolic modeling (with the usage of slice technique) of protocols, programs, models and other behavioral specifications given in behavioral algebraic expressions;
- Map symbolic modeling to original language specifications.

4. SymTech Platform

SymTech is a system with the use of Symbolic Technology, which involves algebraic and deductive formal methods for the resolution of sophisticated industrial challenges.

The main features of SymTech Platform are:

- testing technologies;
- model-driven development;
- support of the development process of a critical system or system with Quality of Service (QoS);
- verification and validation;
- cybersecurity.

4.2 Functionality of the Platform. Main Window

SymTech (Symbolic Modeling) platform includes a number of system and libraries for implementation of the algebraic formal methods and integration with other program systems.

To get started, you must log in to your account on the platform. Once you have logged into your account, you can create a new project, or open a previously created one. After creating a new project, you will see the following arrangement of menus and windows (Fig. 1):

Thus, we have a vertical and horizontal menu for our platform:

- Horizontal menu. Gives us possibilities to make some manipulations with project, such as: back to previous and next action; create, save, start, copy, export or import of project; creation of different experiment with a model, creation a copy of experiment.
- Vertical menu. In this menu we see the list of items that are the key definitions of formalization and are the basis for model formalization and, also a list of special platform tools.

As you can see, the main workspace is occupied by such windows as "protocol", "behavior", "console", etc. (Fig.1). They open by default, but can be closed, minimized or maximized depending on your needs. In these windows, after creation, will

be displayed the key elements of the model, startup results (in console), etc. We also will use them to edit and describe the necessary elements.

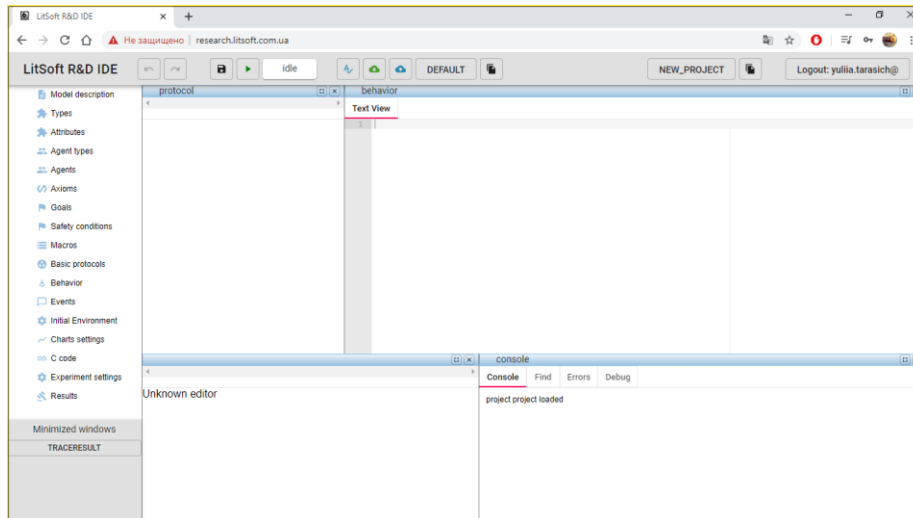


Fig. 1. SymTech (Symbolic Modeling) platform

Let's consider the main functionality of the platform on the concrete examples.

4.3 Examples of Models Formalization. Requirements for a Model. Coffee Machine.

In this example we describe the model of how a coffee machine works.

We have an automated machine which interacts with the external environment by means of coins - input data, of certain denomination and two buttons - «Make coffee» and «Cancel». Requirements for the operation of a coffee machine are given below.

Requirements for the operation of a coffee machine.

- R1. The coffee machine contains slots for 5, 10, 25, 50 cent coins, display and sensor buttons «Make coffee» and "Cancel".
- R2. The coffee costs 95 cents.
- R3. After inserting coins into the slot corresponding to the amount, the sum will be shown on the display.
- R4. If the total of inserted coins is greater or equal to 95 cents, then after pressing the button «make coffee» a drink is delivered and the corresponding change returned.
- R5. Upon pressing the button "Cancel," after inserting coins, the total amount will be refunded.

The example contains agent – automatic machine which interact with the external environment.

Requirement R1 states that the agent - automatic machine communicates with the environment by means of coins - input data, of certain denomination and two buttons, which can be written as the following, having entered the appropriate integer attribute coin, satisfying the condition:

$$(coin = 5) \vee (coin = 10) \vee (coin = 25) \vee (coin = 50)$$

Requirement R2 says that there is a certain factor that contains attributes of price, which can be written down as the following:

$$CoffeePrice = 95$$

The requirements enclose one more attribute related to the amount of inserted coins. Let's designate it by means of the identifier "SUMMA."

It is also required to define the obvious fact that if no coins were inserted into the automatic machine, then $SUMMA = 0$. Thus the agent is formed with variety of attributes which form its type.

For creating a model at the platform we must make next steps:

1. **Add an Agent Types and Agent Attributes.** Add an Agent Types and Agent Attributes. In the vertical menu you can see item "Agent types" (Fig.2 (a)) in that we can add types of agents. After that we can choose needed agent type and in the special window we can add agent attributes (Fig.2 (b)).

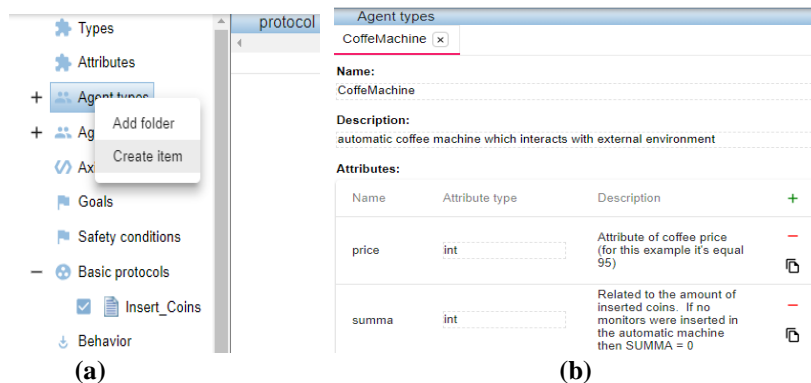


Fig. 2. "Agent types"

2. **Add an Agents.** After the finishing of the describing of all agents types, we must add the instances of agents. In our example, it's only one agent. The agent name is CoffeeMach1 and its type is CoffeMachine (Fig.3(b)).

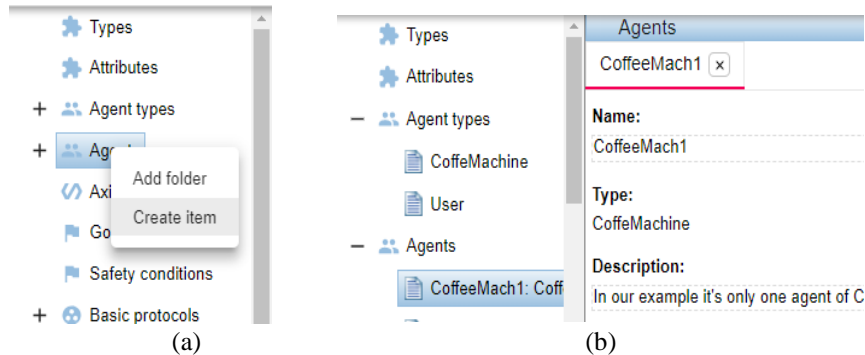


Fig. 3. Agents

It is important to identify the type of agent in those cases when there are only a few of them and the agent expressions shall be used for making these distinctions. In this simple given example, so long as there is only one agent we can consider agent attributes as attributes of the environment.

3. **Add Trigger Events.** The next step is to determine all trigger events (Fig.4). Requirements R3, R4, R5 describe the reaction of the agent to exposure in the environment. They explicitly define trigger events – insert coins, press button “make drink,” push button, “return of the sum.” Thus, preconditions for triggers - presence of inserted amount and the fact that the inserted sum is greater or equal to the price of coffee - are explicitly defined.

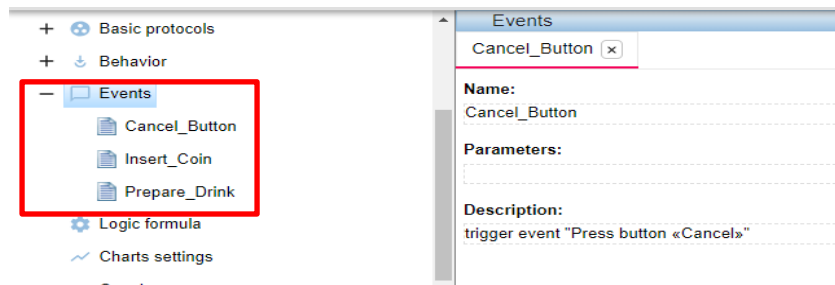


Fig. 4. Trigger events

Such as one of the trigger events is "insert coins," so we declare, for this event, the parameter x of integer type.

4. **Add Basic Protocols.** All basic protocols are presented in the list of "Basic protocols" in the vertical menu. Any of them must be described on the special tab "Basic protocols". Their MSC-diagrams must be described on this tab too (Fig.5).

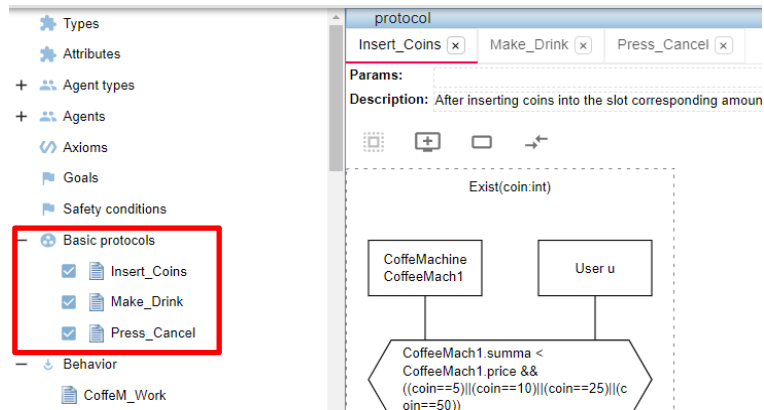


Fig. 5. List of basic protocols

It should be mentioned, that the attribute coin was not defined at first. The attribute coin in Insert_Coins protocol is used as a parameter of basic protocol or local attribute whose value is saved only during the execution of basic protocol. After the application of a basic protocol, it becomes indefinite again.

5. Initial Environment. In the Initial Environment we describe the initial values (Fig.6)

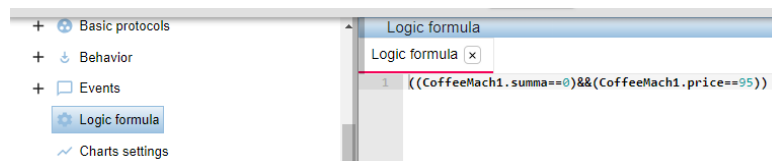


Fig. 6. Initial Environment

6. Behavior. Requirements do not clearly define a certain sequence of application of basic protocols. Initially, only the R3 protocol can be applied and the rest after including itself. After the R4 protocol it is possible to repeat preparation of new portion of drink or complete operation. This sequence is represented in the form of the following UCM-diagram (Fig.7)

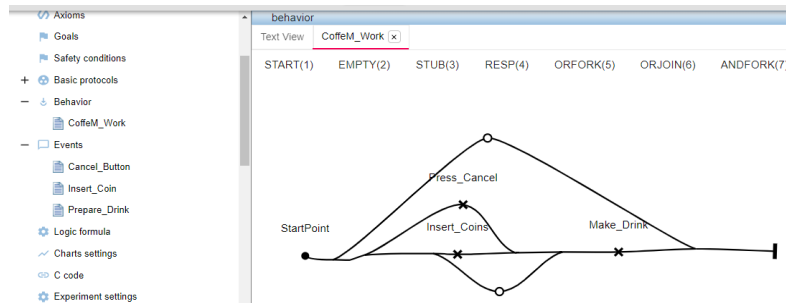


Fig. 7. UCM-diagram CoffeeM_Work

The reflection of UCM-notation in a text form must be written in the tab "TEXT." For this example, we have the following description (Fig.8).

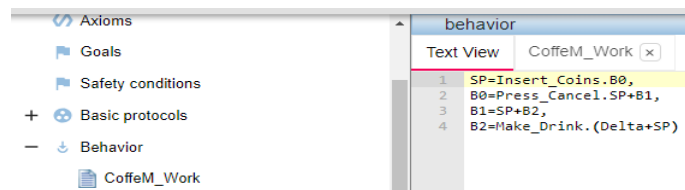


Fig. 8. UCM-notation in a text form

7. **Simulation results.** After starting the program of trace symbolic generation, we get a result, where the behavior of the model is represented by eighteen traces (Fig.9).

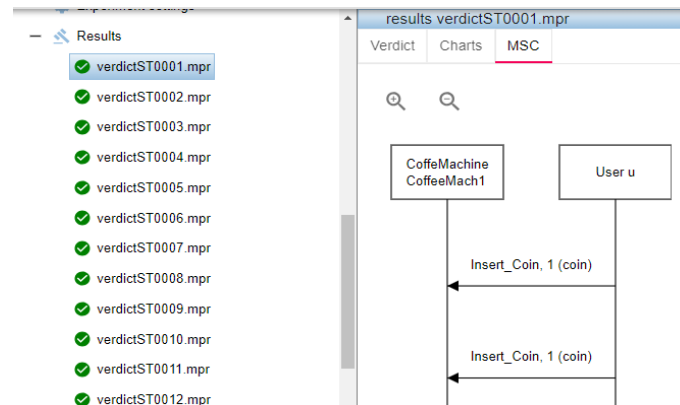


Fig. 9. Simulation results

The text verdict which contains the statistics of trace generation is created after the end of the operation of trace generation. The number of traces, which leads to the

state determined by goal, state the formula such as deadlock states, visited states, states of safety violation and states of possible non determinism is displayed.

The statistics of basic protocol application and the list of not applied basic protocols are provided. The time of trace generation is also documented.

In the given traces information display regarding the symbolic state of the environment, is disabled and there are only those elements illustrating the application of basic protocols, namely messages in the form of arrows and the local actions of an agent.

5 Examples of Projects.

5.1 SKILLONOMY Project

SKILLONOMY is an educational online platform that tokenizes productive activities in the learning process and is focused on gaining monetized online knowledge and skills. The SKILLONOMY ecosystem is built around an IT platform that allows participants to effectively build and administer the relationships that are related to training, investing and sharing experience. Developing the SKILLONOMY project required a set of essential functions of the blockchain for ensuring a stable and efficient system that works [26].

The main purposes of the tokenomics model formalization of the SKILLONOMY project are:

- the search for modeling errors, such as finding failings or possible contradictions;
- the search for effective scenarios of the system in the model, etc.;
- the possibilities for analyzing and predicting the model; and
- the possibilities for analyzing the feasibility of project financing.

The process of the formalization of the tokenomic project consists of the following steps: selection of the agents and definition of their attributes corresponding to the level of abstraction demanded, definition of agents' actions and the design of agents' behavior.

As a result of the simulation of the model and with the selection of different values of attributes, we were able to analyze the behavior of the SKILLONOMY model according to different bitcoin trends.

When we model the specifications, we simulated the activity of all agents that take part in such processes as sending and receiving tokens and selling and purchasing tokens on the stock exchange. In the process of modeling, we were able to monitor the dynamics of attributes and main tokenomic indicators. Moreover, unlike to previous results, in the latest version of model we have modeling the situation when in the system can be present two or more students group and the number of students may increase.

This model allows changing hypotheses to evaluate the risks when selecting the worst conditions in the process of tokenomic modeling. One of most important ad-

vantages of tokenomic modeling is the opportunities to debug the system and to change the algorithm or boundary values of attributes to reach the demanded results.

Description of the model is given in [13-15].

5.2 Cybersecurity Projects

The algebraic approach in cybersecurity was demanded over the past two decades with the appearance of efficient solving and deductive tools. Different techniques like symbolic modeling and concolic computations use the algebraic approach that has created more possibilities for methods of detection in cybersecurity.

Our tools anticipate algebraic matching in different modes. The following applications are available and are under active research:

1. *Definition of Attacker Behavior*

The project has been started together with the Glushkov Institute of Cybernetics in 2017. The goal of the project is to use the algebraic formal methods in the detection of attack and vulnerability in the software systems.

One of the decisions is the usage of behavior algebra algorithms and the theory of insertion modeling. Types of intruder attacks from CVE database, especially Meltdown and Spectre are presented as behavior algebra expression and detection of vulnerability is defined by resolving of behavior.

2. *Vulnerabilities Detection*

The project has started 2016 year with the attempts to formalize the vulnerability “Heartbleed” and try to detect it in Algebraic Programming System.

The results (together with V.Sukhomlinov from Intel) are presented in a paper [27].

The technology of vulnerability formalization has been developed together with the Institute of cybernetics. The technique of vulnerability semantics presentation in behavior algebra expressions has been presented in papers [28, 29]:

The main benefit of an algebraic approach is that we can more accurately detect vulnerabilities. The description of the vulnerability covers a set of its possible scenarios.

The implementation of two or more matching levels can significantly increase the detection efficiency. Thus, matching at the control flow level can be implemented first as a fast procedure, and then, the detected set of scenarios can be modelled symbolically as the more expensive stage.

5.3 Tax Code.

We considered the subset of Tax Code and created its formalization that contains all articles belonged to VAT (Value Added Tax) and its dependencies from additional by-laws.

For presentation of algebraic model we use double sort algebra that contains the algebra of behavior and logical language with arithmetic, set-theoretic and logic oper-

ations. Formulas of this language are constructed from operations and predicates over integer, real, enumerated, and symbolic types [30].

Usually in Tax Code we have two kinds of agents that are – tax payer and taxation office. We can consider the set of Tax Payers that interact with each other.

The given approach could be applied to legal requirements that could be formalized by such manner. We can watch the possible scenarios and analyze the environment in system to achieve the right formal presentation. The traces were verified by third person with economic background and corresponding correction were made.

Now the “digital” Tax Code of Ukraine is ready for use in the scope of Algebraic Programming System and could be deployed in interested organization.

Description of the model is given in [16].

6 Conclusions

Behavior algebra and basic protocol specifications are used for the formal description of a model. Algebraic artifacts such as theorems and abstract algorithms provide a basis for formal verification methods. These methods were implemented and successfully applied to industry projects in Motorola, Inc.

Formal verification anticipates the checking of the properties of the system. The properties could be classic, such as the absence of deadlocks and non-determinisms, or subject domain specific defined safety or liveness conditions. We can prove the reachability of demanded properties by using a symbolic modeling method developed in the scope of IMS.

The given approach could be applied to models that could be formalized by such manner. One of the difficulties is the process of formalization. Due to the experience there should be two specialists involved in the process of the formalization – algebraists and specialist in specific area of project.

Acknowledgements

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A Roadmap for Implementing the Sustainable Software Engineering Curricula in Ukraine According To European E-Competence Framework and Student-Centered Learning Conception

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Abstract. The paper focuses on and propose the semi-formal method of constructing individual educational students trajectories for the professional training of future software engineers in Ukrainian universities. The method for the student-centered learning conception support presented by the authors was developed using graph theory. The set of educational paths that the student is invited to choose corresponds with the requirements of IT enterprises and provides the student with the opportunity to choose his or her educational path for the level of education legally enshrined in Ukraine. The article presents the result of educational trajectories constructing for the process of the professional training of future software engineers from a Junior Bachelor level to Doctor of Philosophy. Ukrainian universities can use the proposed educational trajectories of the professional training of future software engineers for curricula and syllabus preparation. The practical development of this work is an interactive online assistant that will recommend to the student the choice of the educational path from the already achieved level to the target level, which the student will choose.

Keywords: competence, curricula, student-centered learning, sustainability, software engineering, standards.

1 Introduction

In our volatile, intimately connected, and dangerously vulnerable world educational system must be anticipative because the future is far from a linear extension of the past [1]. The article [2] introduces an emerging sustainable learning and education philosophy of learning as a fundamental principle of the sustainable curricula building with appropriate methods of learning and teaching.

M. Knowles is the creator of the concept of self-directed learning, proved that all individuals by nature could be self-directed, even if they need help to get started [3].

The paradigm shift from teaching to learning has contributed to the transfer of power from teacher to student. The teacher should be a "facilitator of the learning process." In the 1980s, this student-centered learning (SCL) concept was transformed by C. Rogers into the theory of education [4].

The works of John Dewey [5] and Carl Roger [6] about personality formation have significantly influenced to SCL. They criticized the obsolete model of education, in which the teacher assigned the central role, and the student is a passive participant in the educational process. Scientists focused that students are as equal partners as a part of the academic community, and coproduces of knowledge is essential for giving student ownership and responsibility for their learning.

SCL has repeatedly demonstrated superiority over the traditional teacher-oriented approach. The research of the Erasmus+ [7] shows that SCL is introduced in different professional fields, different geographical areas, and that it can be practiced even in big classes. The impact of SCL on learning outcomes is confirmed by [8]. The authors confirm advances in designing an SCL process using cutting-edge methods, tools, and artificial intelligence. The authors [9] proved that SCL means that learning outcomes must meet the needs and expectations of students and society while providing employment and personal development.

Nowadays, a joint project of the Union of Higher School Employees (EI) and the European Union of students (ESU) [10] has proposed the main principles and recommendations that underpin in SCL. The project aims to re-evaluate the progress of implementation of SCL, highlight best practices, and establish peer assessment procedures for the implementation of the conception in European higher education institutions. Inspired by the growing interest and progress in implementing SCL, the European Students Union (ESU) developed a new project called Peer Assessment of Student-Centred Learning, funded with the support of the European Commission [11]. Through the research done in this project, the conception of learning outcomes forms the conceptual core for SCL higher education system.

Competencies are one of the main categories of SCL. Fundamental to our study is the competency-based approach (CBA), which based on the concepts of competency and competence. Competence as a complex object includes substantial components, based on knowledge, skills, experience [12]. European e-Competence Framework (e-CF) [13] provides a reference of 40 competencies applied to the field of Information and Communication Technologies (ICT) using a common language of competences, skills, and capability levels.

The work [14] presents an approach to the curricula building as a combination of academic competences and professional competences from the e-CF. The authors developed a competences description for 16 disciplines for proposed a Joint Master Program in Software Engineering. Zaitseva L. [15] pays our attention to the definition of 9 competencies in the Bachelor and 15 competencies in the Master study formed during the acquisition of the study course "Software Engineering" at Riga Technical University on the e-CF base. Evaluation of practical assignments allows assessing the achievement level of the required competencies. Fitsilis P. et al. [16] propose to use a conceptual grid to address different skill needs in different workforce segments in different sectors, depending on different subsets of the technologies. The proposed competence framework consists of six dimensions (proficiency, technology, industry sector, product lifecycles, job profile, and transversal skills) that need to be combined

in order to produce the training needs for each specific case or to calculate the skilled coverage when the readiness of enterprises for introducing Industry 4.0. Liagkou V. et al. proposed an innovative online methodology to evaluate student's competencies and achieved learning outcomes [17]. The core of the methodology is an Engineering Competence Evaluation Internet Portal. The portal provides to the students and professors an innovative research-based online tool, which facilitates the exchange of information on learning outcomes, referring to a graduate's knowledge, skills, and e-CF competence upon completion of their Master of Science in Software Engineering Program.

The European ICT Professional Role Profiles make a crucial contribution to increasing transparency and convergence of the European ICT Skills landscape [18]. Incorporating the competences of the European e-Competence Framework as the main component of profile descriptions, the 30 ICT Professional Role Profiles provide a generic set of typical roles performed by ICT Professionals in any organization, covering the full ICT business process. Complementary to the e-CF, the European ICT Professional Role Profiles contribute to a shared European reference language for developing, planning, and managing ICT Professional needs in a long-term perspective and to maturing the ICT Profession overall.

However, educational standards and training programs at various levels are often not harmonized, based on incompatible competency systems, which leads to problems. It does not allow ensuring the continuity of educational programs at various levels, the possibility of reducing the learning duration and supporting individual educational trajectories of students. The presence of an extensive list of competencies inevitably complicates the development of appropriate assessment tools and methods to test the level of their formation among student

Vocational education and training reform and the Law on Professional Pre-higher Education establish a Junior Bachelor's Degree, which aims at training skilled workers in Ukraine. Junior Bachelor's Degree corresponds to the sixth level of the National Qualifications Framework (Initial level – the short cycle of higher education) [19]. The National Qualifications Framework agreed upon the Qualifications Framework of the European Higher Education Area and the European Qualifications Framework for Lifelong Learning. The Junior Bachelor's Degree (named associate's or foundation degrees in different countries) is an academic program taken at the undergraduate level. The Junior Bachelor's in Software Engineering must acquire the necessary technical and academic knowledge and transferable skills they need to go on to employment or further study.

In the formation and implementation of SCL university professional standard for training software engineers at Ukrainian universities, one must proceed from the fact that each level of higher education and the corresponding professional standard (educational-professional and educational-scientific) is an integral part of the process, which provides for consistency, continuity, and regularity. SCL in the professional standard cannot be fully implemented without individual educational trajectories for training software engineers. Actually, in the education system, individual educational trajectories of training should begin at the level of the Junior bachelor's programs. University educational programs at the Bachelor's level should continue the Junior bachelor's programs, be associated with them, but do not repeat them. At each next

level of higher education, the role and practice of applying an individual learning trajectories students should increase.

In this paper, we adapt our previously developed general approach [20] to the changes that have taken place over the past 1-2 years in educational and professional spheres. We solve the task of constructing educational trajectories for training software engineers at Ukrainian universities. These trajectories must fit the qualifications framework and must support the SCL conception.

The paper is structured as follows. Section II presents the theoretical basis for the reasoned choice of the individual educational student trajectories according to the European e-competence framework. Section III presents the results of the proposed method according to the European e-competence framework for Software Engineering specialty.

2 Method of Constructing Individual Educational Students Trajectories According to European E-Competence Framework

2.1 Input Assumptions and Limitations.

The target competencies for training specialists in Software Engineering (SE) must provide training for profiles "Developer" and "Test Specialist" because these profiles fully meet the qualifications of Degree "Specialist in the development and testing of software" by the National classification of professions Ukraine. Since the profile "Digital media specialist" is very close to the two profiles above for the necessary competencies [21], we assume that these three profiles will form the core and start point for the specialty "Software engineering."

The target competencies that Developers, Digital Media Specialists, or Test Specialists must possess are limited to the third level of E-CF, which corresponds to the bachelor's level both in the European Qualifications Framework and the Law on Higher Education of Ukraine. Therefore, to continue training to the level of a master or a doctor of philosophy is pointless.

The choice of further educational paths should be justified, proceeding, first of all, from the desired target profile. The criterion for the validity of the choice of an educational trajectory is the minimum difficulty in acquiring new necessary competencies and increasing the level of competencies already achieved at the previous level of education. In our opinion, this complexity can be quantified by summing up the number of new competencies required, taking into account their level and the number of the new deliverables for which the future graduate will be responsible.

Only training paths for which the difficulty measured by the above method is small enough can be recommended for training. Obtained with this method of measuring assessments of the complexity of training will be more likely to be qualitative, relative, and will never become accurate, quantitative. In our opinion, the result we obtained is entirely consistent with the stated goal of the work: to formulate recommendations for the student on the choice of the educational path in terms of "it is easy," "it is harder," and "it is almost unattainable."

We are in no way trying to express numerical recommendations of the form "Training to achieve at the level of the philosophy doctor of competencies required to work on profile X will be many times Y more difficult than preparing you for work on profile Z." In our opinion, this is justified, the reasoned approach to the maximum extent corresponds to the concept of Student-Centered learning, as it allows each student to plan personally and, if necessary, adjust their path in their education.

2.2 The Formal Statement of the Problem.

The initial data are the interrelations matrixes of the "ICT profiles – E-competences" and "ICT profiles – Deliverables." In the mathematical representation, these tables define two bipartite graphs (mappings):

$$\Phi_1: P \rightarrow C, \Phi_2: P \rightarrow D, \quad (1)$$

where $P = \{P_1, P_2, \dots, P_{30}\}$ – the profiles set,

$C = \{C_1, C_2, \dots, C_{40}\}$ – the competences set,

$D = \{D_1, D_2, \dots, D_{76}\}$ – the deliverables set.

The mapping of the profiles set to the competences set we present as $G = \langle P, C, E \rangle$, where E denoting the weighted edges set of the bipartite graph. The weight of each edge $e_{p,c}$ we define as the level of the competence with number c, which is needed to profile with number p. Similarly, the mapping of the profiles set to the deliverables set is $H = \langle P, D, K \rangle$, where K denotes the edges of the bipartite graph and each edge $K_{p,d} \in \{0,1\}$.

The proximity function between any two profiles s and t we define as distance in an undirected graph:

$$\text{Pr}(s, t) = \alpha \sum_{\forall c, c \in C} \min(e_{s,c}, e_{t,c}) + (1 - \alpha) \sum_{\forall d, d \in D} k_{s,d} k_{t,d}, \quad (2)$$

where α - coefficient that allows controlling the importance of proximity metric according to common competencies relative proximity metric according to shared deliverables. The complexity function of the transition to a new profile t in the presence of competencies of the existing profile s we introduce as a distance in a directed graph:

$$\text{Dif}(s, t) = \alpha \sum_{\forall c, c \in C \cap (e_{t,c} > e_{s,c})} (e_{t,c} - e_{s,c}) + (1 - \alpha) \sum_{\forall d, d \in D \cap (k_{t,d} = 1)} (k_{t,d} - k_{s,d}) \quad (3)$$

The assumption that training is carried out in consistent progress through the educational levels leads to a search all possible pairs s and t within a stepwise education system with the suggestion that these pairs must satisfy the following condition:

$$\max_{\forall c, c \in C} (e_{t,c}) - \max_{\forall c, c \in C} (e_{s,c}) = 1 \quad (4)$$

We introduce the reachability matrix of the next target profile, starting with the existing one. In graph theory, reachability refers to the ability to get from one vertex to

another within a graph. A vertex s can reach a vertex t , and t is reachable from s if there exists a sequence of adjacent vertices (i.e., a path) which starts with s and ends with t .

Taking into account constraint (4), the reachability matrix we present as:

$$Reach(s, t) = \begin{cases} \frac{1}{d_{if}(s,t)}, & \text{if condition (4) true} \\ 0, & \text{otherwise} \end{cases} \quad (5)$$

2.3 The Constructing Individual Educational Trajectories Set and Curricula Set

The method of constructing individual educational trajectories set and curricula set as a result is a sequence of following steps.

Step 1. Clustering profiles, as the process of ordering of profiles graph structure into relatively homogeneous groups, where the proximity function between any two profiles is calculated according to (2). We used the modularity metric proposed in the paper [22] for clustering. The metric value lies between 0.5 and 1, calculated by the formula:

$$Q = \frac{1}{2m} \sum_{s,t} \left(Pr(s, t) - \frac{d_s d_t}{2m} \right) \delta(k_s, k_t), \quad (6)$$

where d_i is the degree of the i -th node, K_i is the cluster in which i -th node is located, m is the number of edges in the graph. $\delta(k_s, k_t) = 1$, if $k_s = k_t$, otherwise 0.

Using the modularity metric (6) allows us to split the initial list of profiles into profile clusters, which are characterized by a strong connection of profiles within classes and weak for profiles located in different clusters (strong link inside and weak ones among groups). A change in the coefficient makes it possible to evaluate the stability of the clustering result when changing the evaluation criterion from proximity by competencies to proximity by deliverables.

Step 2. The reachability graph describes the ability to get from obtained profile to the next one by educational level with quantity estimation of this step complexity. The reachability graph is constructed by using (5) and is become a background for building individual educational trajectories set.

Step 3. The curricula set is constructed using individual educational trajectories set. The start point for each curricula building is the needing competencies for goal profile, knowledge, and skills examples, cataloged in the e-CF.

3 Individual Educational Student Trajectories According To The European E-Competence Framework

We performed a profile's clustering from e-CF with $\alpha = 1$ from (2), taking into account only the quantity of common competencies required for each pair of profiles. As a result, we got seven closely related groups (fig. 1). Each group has its color, and

the line thickness between each pair of profiles is proportional to the number of shared competencies.

The aimed group includes next roles:

- Developer.
- Digital Media Specialist.
- Test Specialist.
- DevOps Expert.
- System Administrator.
- Network Specialist.

Grouping of profiles by Deliverables/Outcomes proximity principle with $\alpha=0$ from (2) gives the partially different result (fig. 2). A Deliverable, according to e-CF, is a predefined result of a task in a job context. Deliverables describe typical outcomes of a solved task in terms of accountable, responsible, or contribution. When clustering according to the proximity by Deliverables/Outcomes, the aimed group includes next roles:

- Developer.
- Digital Media Specialist.
- Test Specialist.
- DevOps Expert.
- Systems Analyst.
- Systems Architect.
- Digital Transformation Leader.

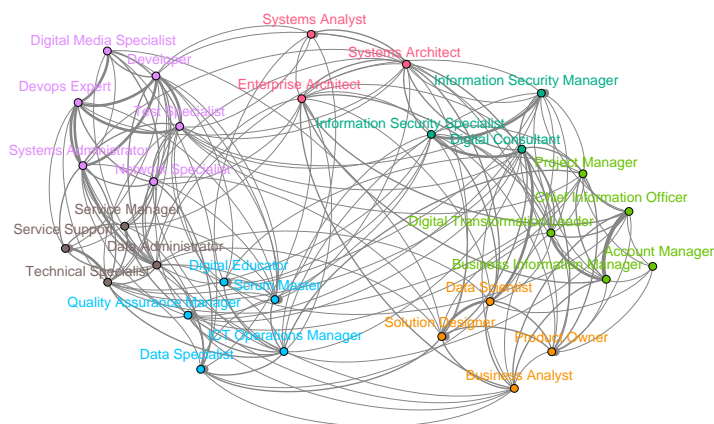


Fig. 1. Seven profiles groups (highlighted by different colors) which are closely related by the list of required competence

All recommended trajectories for achieving the desired profiles for software engineering are presented in fig. 3. The line thickness characterizes the number of competen-

cies achieved at the previous level that will be claimed at the next one, that is, the thicker the connecting line, the easier it will be to achieve the target profile.

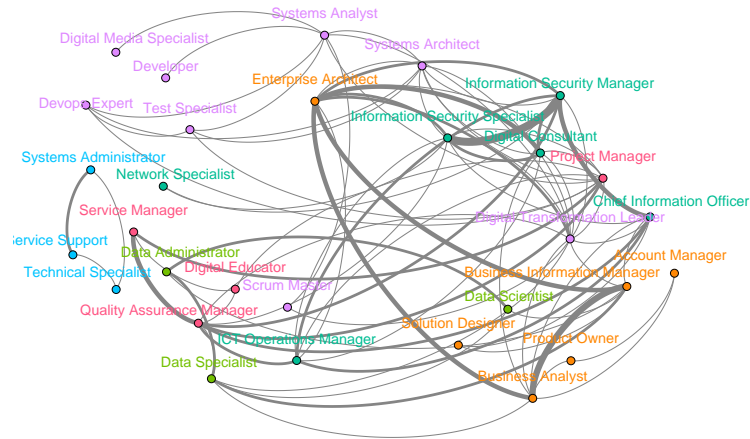


Fig. 2. Seven profiles groups (highlighted by different colors) which are closely related by the deliverables

Table 1 details recommended individual educational students trajectories, starting from the software engineering profiles (Developer, Digital Media Specialist, Test Specialist), which are available from junior bachelor level.

Table 2 contains reference information about deliverables and competencies, which must be formed or improved during the transition from systems architect role profile to digital transformation leader role profile.

4 Conclusions and Future Work

The key performance indicator for Student-Centred Learning is student satisfaction with the incorporation of sustainable curricula. The e-CF has proved to be very useful in the process of curricula design because one of the critical challenges of effective curricula design is managing how different stakeholders communicate and cooperate in designing curricula that meet both educational and employer objectives.

The article proposes a partial formalization of the method of constructing educational trajectories for training software engineers at Ukrainian universities. Improving student knowledge, skills, and competence without a clear plan and goal as to how that future Bachelor, Master, or Ph.D. will correspond to the organizational needs of an employer generally has minimal effect. Students should understand the general learning objectives and not learn in fragments without any apparent purpose. The effective use of individual SCL should be coordinated holistically to provide adequate support to the needs of the employer organization.

Table 1. Recommended individual educational students trajectories according to Software engineering profiles (only for profiles inherited from Developer, Digital media specialist or Test specialist with Junior Bachelor level)

Profile	ICT Profile Families	Proximity by competencies	Proximity by deliverables	Educational level
Developer	Development	+	+	Bachelor
Digital Media Specialist		+	+	
Test Specialist		+	+	
System Administrator	Service & Operation		+	
Network Specialist			+	
Systems Analyst	Design	+		Master
Systems Architect		+		
DevOps Expert	Process Improvement	+	+	
Digital Transformation Leader			+	Doctor of Philosophy

Table 2. Summary table describing the needed competencies and deliverables of the transition from systems architect role profile to digital transformation leader role profile

	Systems Architect	Digital Transformation Leader
Deliverables	Solution Specification	
	Integrated Solution	
	Development Process	
	Solution and Critical Business Process Integration Proposal	
		Digital Transformation Roadmap
		Digital Transformation Strategy
Competencies	A.7. Technology Trend Monitoring	
	B.2. Component Integration	
	B.6. Systems Engineering	
	A.5. Architecture Design	
	A.9. Innovating	
		A.3. Business Plan Development
		E.7. Business Change Management

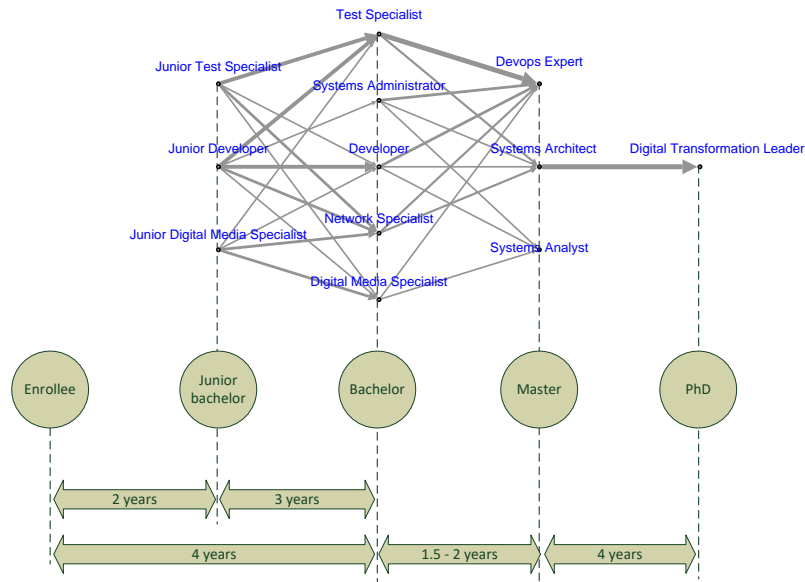


Fig. 3. Trajectories (possible paths) for achieving the desired profiles for software engineering with accounting common competencies and deliverables (the line thickness characterizes the number of competencies achieved at the previous level that will be claimed at the next, that is, the thicker the connecting line, the easier it will be to achieve the target profile)

The set of educational trajectories (individual paths) that a student is offered to choose must meet the requirements of IT enterprises, fit the qualifications framework, and must support the SCL concept, that is, enable the student to choose his or her educational path for one from the educational levels legally enshrined in Ukraine.

The following features of software engineering and higher education in Ukraine are taken into account.

1. The target competencies that Developers, Digital Media Specialists, or Test Specialists must possess are limited to the third level of E-CF, which corresponds to the bachelor's level both in the European Qualifications Framework and the Law on Higher Education of Ukraine. Therefore, to continue training to the level of a master or a doctor of philosophy is pointless. The choice of further educational paths should be justified, first of all, from the competencies desired target profile.
2. Vocational education and training reform and the Law on Professional Pre-higher Education establish a Junior Bachelor's Degree, which aims at training skilled workers. Junior Bachelor's Degree corresponds to the sixth level of the National Qualifications Framework (Initial level – the short cycle of higher education) [23]. The National Qualifications Framework agreed upon the Qualifications Framework of the European Higher Education Area and the European Qualifications Framework for Lifelong Learning. The Junior Bachelor's Degree (named associate's or foundation degrees in different countries) is an academic program taken at the undergraduate level. The Junior Bachelor's in Software Engineering must acquire the

necessary technical and academic knowledge and transferable skills they need to go on to employment or further study.

The proposed method for the set constructing of the software engineer's educational trajectories in Ukrainian universities uses graph theory. The nodes of the weighted graph are the roles proposed by the European e-Competence Framework, and the weights of the edges characterize the number of competencies achieved at the previous level of education that will be necessary to achieve the next level. Each trajectory is a path starting from the enrollee-node and ending on the master level or Ph.D. level node. An additional metric of the distance between nodes calculates the total number of deliverables shared by these roles.

Each person selects their trajectory personally; therefore, the mathematically solved problem belongs to the class of tasks in which it is required to list all implemented trajectories for future choice. After that, the student must choose his learning path, and the university must build the educational programs necessary for the implementation of the required trajectories.

The article presents the result of the synthesis of educational trajectories for software engineering from a junior bachelor level. It is shown that the subsequent levels of education should be oriented toward acquiring the competencies necessary for the DevOps Expert Role, Systems Architect Role, or Systems Analyst Role at the master's level. If a student plans to achieve the level of Doctor of Philosophy, starting from the three listed above Junior Bachelor's Degrees, he or she should choose only the Systems Architect Role at the Master degree, since only this role is firmly connected by common competencies and deliverables with the Digital Transformation Leader Role.

Further development of the work is planned in the practical implementation of an interactive online assistant, which will formulate recommendations for the student on the choice of disciplines, forming a set of trajectories from the already achieved level to the target one that the student will choose.

5 Acknowledgment

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On Induction for Diamond-Free Directed Complete Partial Orders

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Abstract. A formulation of an induction principle for diamond-free directed complete partial orders is proposed. This principle may be useful for specification and verification of non-discrete systems using interactive proof assistant software.

Keywords: Formal methods, partial order, real induction, open induction.

1 Introduction

Inductive proofs and recursive definitions are very useful tools in software specification and verification. In particular, they are frequently used in formalizations of algorithms in proof assistants such as Isabelle and Coq. This leads to a question of whether certain analogous proof methods and corresponding definition methods may be useful in the case of specification and verification of cyber-physical systems, in particular, using proof assistants. Since in this case one is expected to deal with formalization of properties which involve continuous variables, investigation of generalized inductive proof methods and recursive definitions which use a continuous parameter is relevant.

Proof principles that allow one to prove a property of real numbers by an argument that is in some sense similar to mathematical induction may be called real or continuous induction principles [1–3]. An overview, literature references and applications related to this topic can be found in [1, 2].

Recently, real induction was used in differential equation invariance axiomatization [4, 5] which extends a logic (differential dynamic logic [4]) intended for verification of hybrid systems (which may be used as mathematical models of behaviors of cyber-physical systems).

The real induction principle referenced in [4] is given in [2, Theorem 2]. It states that a subset $S \subseteq [a, b]$ ($a < b$ are real numbers) is inductive if and only if $S = [a, b]$. Here a subset $S \subseteq [a, b]$ is called inductive, if it satisfies the following properties [2]: (1) $a \in S$; (2) if $a \leq x < b$, then $x \in S$ implies $[x, y] \subseteq S$ for some $y > x$; (3) if $a < x \leq b$ and $[a, x] \subseteq S$, then $x \in S$.

A more general theorem which characterizes Dedekind-complete total orders is also given in [2].

A discussion of a question about generalization of a slightly different theorem for total orders to an induction principle for partial orders and a formulation of an induction principle for complete lattices can be found at [6].

However, in formal methods and verification, some posets of interest do not form lattices. One example is the set of partial trajectories of a *nondeterministic* (possibly hybrid) dynamical system, defined on time intervals of the forms $[0, t)$, $[0, t]$, ordered by the extension relation ($s_1 \leq s_2$, if s_2 extends s_1), where diverging trajectories (incomparable elements) have no joins.

But in this example and in some other, a poset of interest belongs to the class of diamond-free posets, i.e. posets such that there is no tuple (a, b, c, d) in which $a \leq b \leq d$, $a \leq c \leq d$, and b, c are incomparable.

In this paper we will argue that Raoult's open induction principle [7] can be used to obtain an induction principle for diamond-free directed complete partial orders (dcpo) which extends the real induction principle.

2 Preliminaries

Let (X, \leq) be a poset and $A \subseteq X$ be a subset. We will use the following notation:

- $<$ is the strict order which corresponds to \leq ;
- $[a, b]$ is the set $\{x \in X \mid a \leq x \wedge x \leq b\}$;
- $[a, b)$ is the set $\{x \in X \mid a \leq x \wedge x < b\}$;
- $x = \sup_{\leq} A$ denotes that x is the least upper bound of A in (X, \leq) .

We will assume that the axiom of choice holds.

3 Main Result

Firstly, let us consider the following auxiliary statement.

Theorem 1 (Converse open induction principle). *Let (X, \leq) be a poset.*

Assume that X is the only directed open subset $S \subseteq X$ which satisfies the following condition:

- (1) *for each $x \in X$, if $\forall y \in X (x < y \Rightarrow y \in S)$ holds, then $x \in S$.*

Then (X, \leq) is a dcpo.

Proof. Suppose that (X, \leq) is not directed complete (so (X, \leq) is not chain complete). Then there exists a nonempty \leq -chain $C \subseteq X$ which has no supremum in (X, \leq) . Let C' be the directed closure of C . Let $S = X \setminus C'$. Let us show that S satisfies the condition (1).

Let $x \in X$. Assume that $\forall y \in X (x < y \Rightarrow y \in S)$ holds. Suppose that $x \notin S$. Then $x \in C'$. The set $\{\sup_{\leq} C'' \mid C'' \subseteq C, C'' \neq \emptyset, \text{ and } C'' \text{ has a supremum}\}$ is directed closed. Then $x = \sup_{\leq} C''$ for some nonempty \leq -chain $C'' \subseteq C$. Let us show that C and C'' are cofinal. Let $c \in C$. Suppose that for each $c'' \in C''$, $c < c''$ does not hold. Since $C'' \subseteq C$, each element of C'' is comparable with c . Then c is an upper bound of C'' . Then $x \leq c$. The relation $x < c$ cannot hold,

because it implies $c \in S = X \setminus C'$, but $c \in C \subseteq C'$. Hence $x = c \in C$. Then each $y \in C$ such that $x < y$ belongs to S . This implies that x is the largest element of C . Then $x = \sup_{\leq} C$. This contradicts the assumption that C has no supremum. Thus there exists $c'' \in C''$ such that $c < c''$ holds. Since $c \in C$ is arbitrary, we conclude that C and C'' are cofinal. Then $x = \sup_{\leq} C$ and we get a contradiction with the assumption that C has no supremum. Thus $x \in S$.

Then S satisfies the condition (1). Note that S is directed open. Then $S = X$. Then $C' = \emptyset$ and we get a contradiction with the fact that C is nonempty.

Thus (X, \leq) is directed complete. \square

Theorem 2 (Induction principle for diamond-free dcpos).

Let (X, \leq) be a diamond-free poset. Then (X, \leq) is directed complete if and only if the only subset $S \subseteq X$ which satisfies the conditions (1)-(2) is X :

(1) for each $x \in X$, if $\forall y \in X (x < y \Rightarrow y \in S)$ holds, then $x \in S$;

(2) for each $x \in X$ and $z \in S$ such that $x < z$ and $\sup_{\leq} [x, z] = z$, there exists $y \in [x, z]$ such that $[y, z] \subseteq S$.

Proof. “If”. Assume that X is the only subset of X which satisfies (1)-(2).

Let us show that each directed open set S satisfies the condition (2). Let $S \subseteq X$ be a directed open set, and $x \in X$ and $z \in S$ be such that $x < z$ and $\sup_{\leq} [x, z] = z$. Suppose that for each $y \in [x, z)$ we have $[y, z] \setminus S \neq \emptyset$. Then the sets $[x, z)$ and $[x, z) \setminus S$ are cofinal. Denote $C = [x, z) \setminus S$. Then $\sup_{\leq} C = z \in S$. Moreover, C is a \leq -chain, since $[x, z) \setminus S \subseteq [x, z]$ and (X, \leq) is diamond-free. Since S is directed open, $C \cap S \neq \emptyset$. We have a contradiction with the definition $C = [x, z) \setminus S$. Thus there exists $y \in [x, z)$ such that $[y, z] \subseteq S$.

Thus X is the only directed open subset of X which satisfies the condition (1). Then (X, \leq) is a dcpo by Theorem 1.

“Only if”. Assume that (X, \leq) is a diamond-free dcpo. Obviously, $S = X$ satisfies 1-2. Let $S \subseteq X$ be a set which satisfies 1-2. Let us show that $S = X$.

Firstly, let us show that S is a directed open set.

Let C be a nonempty \leq -chain such that $\sup_{\leq} C = z \in S$.

Let us show that $C \cap S \neq \emptyset$. Without loss of generality, assume that $z \notin C$. Let x be some element of C . Note that $x < z$.

Let $C_1 = \{y \in C \mid x \leq y\}$. Then C_1 is a nonempty \leq -chain. Moreover, C and C_1 are cofinal, so $\sup_{\leq} C_1 = z$. Since $z \notin C$, we have $C_1 \subseteq [x, z)$.

Let $y \in [x, z)$. Since $\sup_{\leq} C_1 = z$, y is not an upper bound of C_1 . Then exists $c \in C_1$ such that $c \leq y$ does not hold. Note that c and y are not incomparable, since $c, y \in [x, z]$ and (X, \leq) is diamond-free. Then $y < c$.

Since y is arbitrary, C_1 and $[x, z)$ are cofinal. Then $\sup_{\leq} [x, z) = z$.

Then from the condition (2) it follows that there exists $y \in [x, z)$ such that $[y, z] \subseteq S$. Since $x \leq y < z$ and $\sup_{\leq} C = z$, there exists $c \in C \cap [x, z]$ such that $c \leq y$ does not hold. Note that c and y are not incomparable, because $c, y \in [x, z]$ and (X, \leq) is diamond-free. Then $y < c$, so $c \in [y, z] \subseteq S$ and $C \cap S \neq \emptyset$.

Since C is arbitrary, this implies that S is a directed open set in (X, \leq) . From the condition (1) it follows that S is the set of elements which satisfy an inductive property in the sense of [7, Proposition 1.2].

Then $S = X$ by the open induction principle [7]. \square

4 Discussion

Similarly to the case of the real induction principle, the conditions (1)-(2) of Theorem 2 can be formulated as a first-order formula in a signature that has symbols for the predicate of membership in S , the relation \leq , and equality.

The condition (1) states that the predicate $P(x) \Leftrightarrow x \in S$ defines an inductive property in the terminology of [7] (which should not be confused with the notion of an inductive subset from [2]). It also corresponds to the formulation of Noetherian induction schema.

The condition (2) is analogous, but somewhat weaker than the formulation of the condition [6, (POI2')] for the opposite order relation (\leq^{-1}).

Theorem 2 is applicable to total orders (which are diamond-free). In the special case when X is the real interval $[0, 1]$ and \leq is a restriction of the order, opposite to the standard order on real numbers, (X, \leq) is directed complete and the “only if” part of the statement of the theorem reduces to the statement that $[0, 1]$ is the only subset $S \subseteq [0, 1]$ which satisfies (1)-(2), where (1)-(2) are equivalent to statement that S is an inductive subset of $[0, 1]$ in terms of [2].

Theorem 2 can also be applied to sets of partial trajectories of nondeterministic continuous-time dynamical systems, defined on time intervals of the form $[0, t)$, $[0, t]$, ordered by the extension relation ($s_1 \leq s_2$, if s_2 extends s_1), or the opposite of this relation (with the dual completeness requirement), assuming that a partial trajectory cannot extend two incomparable partial trajectories (since their domains are \subseteq -comparable).

5 Conclusions

We have proposed an induction principle for diamond-free directed complete partial orders. It can be considered as an extension of the real induction principle for a real interval.

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Machine Learning and Disk-based Methods for Qualitative Verification of Markov Decision Processes

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Abstract. State explosion is a well-known challenge of model checking. In this paper, we propose several approaches to improve the standard techniques for verifying the qualitative reachability properties of Markov decision processes. For the first approach, we use two heuristics to reduce the total number of iterations of the standard iterative methods. The second approach uses the secondary hard disks for storing the information of a model and uses the main memory for a back-ward technique on the standard methods. The third approach uses a machine learning technique to classify the state space of a model to the related classes. While this approach does not need any memory overhead, its running time is much less than the running time of the standard approaches and can be used to cope with the state explosion problem.

Keywords: Probabilistic model checking, Qualitative reachability, Markov decision process, Machine learning.

1 Introduction

Probabilistic model checking is a formal verification technique, used to verify the correctness of computer systems with some probabilistic aspects [1]. Markov decision processes (MDPs) are a well-known formalism for modeling systems that have both non-deterministic and probabilistic behaviors [11, 9, 18]. The main challenge of model checking is the state space explosion problem. In this problem, the number of states of the model grows exponentially in the number of modules of the underlying system [1, 6]. Several approaches are proposed to cope with this problem. Symbolic model checking is a well-established approach that uses a compact data structure to store the information of a model. Binary decision diagram (BDD) is one of the most successful compact data structures that is widely used in successful model checking tools [6]. Multi-terminal BDD (MTBDD) has been developed and widely used for verification of probabilistic systems [17].

However, iterative computations required in probabilistic model checking are computationally expensive where BDD-based data structures are used. As an alternative, sparse matrix representation is used as an explicit approach that stores the information of state-values and transition probabilities of the model. A hybrid approach uses MTBDD for storing the information of transitions and an explicit array for state-values [17].

In this paper, we focus on the verification of qualitative reachability properties of MDP models and propose several techniques to improve the performance of standard iterative algorithms for this class of properties. A qualitative property states that the extremal (minimal or maximal) probability of reaching a set of states is 0 or 1 [1, 9]. Some graph-based computations are needed to compute the related set of states. While BDD-based implementation for computing qualitative reachability properties in MDPs is available in several states of the art model checkers [10, 12], their running time is a main drawback of the BDD-based techniques. To alleviate this drawback, we propose several improvements for computing qualitative reachability properties of MDPs. The forward and backward approaches for the standard iterative algorithms for computing qualitative reachability properties are compared in [16]. While the backward approach is much faster than the forward one, its memory overhead is the main obstacle for this approach. As the first contribution of the paper, we propose several improvements to the forward approach. The general idea of these approaches is to reduce the number of iteration of the standard algorithms. We use the sparse explicit data structure for implementations of these improvements and consider those models that are small enough to load overall information in the main memory. Furthermore, we propose two approaches in the case of larger models that can not be loaded in the main memory. As the second contribution of the paper, we use a disk-based approach to store the transition probability information of a model and load its graphical information to the main memory. In this case, we apply the backward approach to reduce the running time. As the third contribution, we apply machine learning approaches to compute the set of states for which the extremal reachability probability is 0 or 1. For each class of MDP models, we consider several small models for training a classifier and use it to classify the states of a large model to the related sets. Although this technique does not guarantee to find the exact sets, our experiments show promising results with nearly zero error. The main benefit of this approach is its scalability for very large models.

1.1 Related Works

The first algorithms for qualitatively verifying the reachability properties of MDP models were proposed in [7]. The time complexity of these algorithms is linear or quadratic in the size of the model for the minimal or maximal reachability probabilities, respectively [1, 7]. BDD-based and sparse explicit implementations of these algorithms have been proposed and studied in [17]. The worst-case time complexity for qualitative verification of maximal reachability probability is improved in [4]. Decomposing an MDP to its strongly connected

components (SCCs) and computing reachability probabilities of the states of each SCC has been proposed in [13]. In this case, qualitative verification is performed implicitly for each SCC. Although this technique presents promising results in the running time, its focus is on the computations of quantitative reachability properties and does not guarantee the correctness for the results in the case of qualitative verification. The backward and forward approaches for the standard algorithms for qualitative verification of MDPs are studied and compared in [15]. The backward approach for the sparse explicit data structure is supported by the STORM model checker [8]. A linear-time heuristic is proposed in [16] to approximate the qualitative reachability properties in the case of maximal probabilities. In Section 3, we use this heuristic to reduce the total number of iterations for the forward approach. Disk-based techniques have been used in [14] for verification of quantitative properties of very large DTMC and MDP models. In [3] a learning-based approach is used for statistical model checking of MDPs. This approach reduces the visited states of a model and is implemented in the explicit engine of PRISM. In [20], machine learning is employed to approximate the probabilities of an unknown MDP model. In [19] machine learning is used to extrapolate the optimal actions of MDP models. Although the proposed approach in [19] proposes some promising results, it is limited to only a case study and its generality for other models is not explained.

2 Preliminaries

In this section, the main concepts and definitions of probabilistic model checking and qualitative verification of reachability properties are reviewed. More details about the probabilistic model checking and its variant are available in [1, 9, 6]

2.1 Probability Distribution and Markov Decision Process

A probability distribution on a finite set X is defined as a function $Pr : X \rightarrow [0, 1]$ where $\sum_{x \in X} Pr(x) = 1$. We use $D(x)$ to denote the set of all probability distributions on X .

Definition 1. Markov Decision Processes. A Markov Decision Process (MDP) is a tuple $M = (S, s_0, Act, P, G)$ where:

- S is a finite set of states.
- $s_0 \in S$ is the initial state.
- Act is a finite set of actions. For every state $s \in S$, one or more elements of Act are defined as enabled actions and are shown by $Act(s)$.
- $P : S \times Act \rightarrow D(s)$ is a probabilistic transition function. We use (s, α, s') for a transition from the source state s to the destination s' by the action α and $P(s, \alpha, s')$ for the probability of this transitions. For each state $s \in S$ and enabled action $\alpha \in Act(s)$ a probability distribution is defined.
- $G \subset S$ is the (non-empty) set of goal states.

The size of X is defined as the number of its states and transitions and is shown by $|M|$. MDPs are widely used in mathematics, engineering, economics, and management to model decision making under uncertainty in stochastic environments [11, 18]. The actions of MDPs are used to model non-deterministic concepts of a system and its related environment. The probabilistic transition function is used to model the stochastic and probabilistic behavior of the environment.

In formal verification, a high level language is used for modeling computer systems. Every model includes one or several modules. Some variables in a bounded domain are defined for each module. A possible valuation of the variables in a module presents a state of the module for the system. The PRISM language is used as the standard modeling language for probabilistic systems [12]. The interpreter of the model checker constructs the resulting MDP (states, actions, and transition probabilities) according to the definitions of its modules. More details about the PRISM language are available in [17, 12].

2.2 Semantic of MDP

For an MDP M and one of its states $s \in S$, the MDP performs a transition in two steps:

- It non-deterministically selects an enabled action $\alpha \in Act(s)$.
- It randomly selects the destination state $s' \in S$ with probability $P(s, \alpha, s')$.

For any state $s \in S$ and enabled action $\alpha \in Act(s)$, we use $Post(s, \alpha)$ for the set of α -successors of s , $Post(s)$ for all its possible successors, and $Pre(s)$ for its predecessor states:

$$Post(s, \alpha) \doteq \{s' \in S \mid P(s, \alpha, s') > 0\}, \quad (1)$$

$$Post(s) \doteq \cup_{\alpha \in Act(s)} Post(s, \alpha), \quad (2)$$

$$Pre(s) \doteq \{s' \in S \mid s \in Post(s')\}. \quad (3)$$

A path in M shows a possible run and is defined as a non-empty (finite or infinite) sequence of states and actions of the form $\pi = s_0 \xrightarrow{\alpha_0} s_1 \xrightarrow{\alpha_1} \dots$ where for every $i \geq 0$, we have $s_i \in S$ and $\alpha_i \in Act(s_i)$ and $s_{i+1} \in Post(s_i, \alpha_i)$. We use $Path_s$ to denote the set of all infinite paths of M that start from a state $s \in S$. For the subset of finite paths of $Path_s$ we use $FPath_s$. We also use $\pi(i)$ to denote the $(i+1)$ -th state in the path π , i.e., $\pi(i) = s_i$. To reason about the probabilistic behavior of an MDP M , one should resolve its non-deterministic choices. To do so, a deterministic function is used that maps an action $\alpha \in Act$ to each path of M . This function is called adversary (scheduler or policy) and is defined as [9, 6] :

Definition 2. (Adversary). An adversary of an MDP M is a function $\sigma : FPath_s \rightarrow Act$ that for every finite path $\pi = s_0 \xrightarrow{\alpha_0} s_1 \xrightarrow{\alpha_1} \dots \xrightarrow{\alpha_{i-1}} s_i$ selects an enabled action $\alpha_i \in Act(s_i)$. An adversary σ is called memory-less if it depends only on the last state of the path. We use $FPath_s^\sigma$ for the set of all finite paths of the form $s \xrightarrow{\sigma(s)} s_1 \dots s_{n-1} \xrightarrow{\sigma(s_{n-1})} s_n$ that start from s .

In this paper, we only use memory-less adversaries that are sufficient for analysis of reachability properties. We use Adv_M for the set of all (memory-less) adversaries of M .

2.3 Reachability Probabilities

The main class of properties that are used in the probabilistic model checking of MDPs includes the reachability properties. The computation of these properties is usually reduced to the computation of the reachability ones. For MDPs, a reachability probability is defined as the extremal (minimal or maximal) probability of reaching a goal state. For an adversary $\sigma \in Adv_M$ and a state $s \in S$, we define $reach_s^\sigma(G)$ as the set of all finite paths, starting from $s \in S$, ending in G , and selecting actions due to the adversary σ . Formally we define:

$$reach_s^\sigma(G) = \{\pi \in FPath_s^\sigma \mid last(\pi) \in G, \text{ and } \forall i < |\pi| : \pi(i) \notin G\} \quad (4)$$

where $last(\pi)$ is the last state in π . For an adversary σ and a path $\pi \in FPath_s^\sigma$, a probability measure $pr^\sigma(\pi)$ is defined as the product of probabilities of transitions between the states of π :

$$pr^\sigma(\pi) = \prod_{i=0}^{n-1} P(s_i, \sigma(s_i), s_{i+1}) \quad (5)$$

This probability measure is used to formally define the extremal reachability probabilities. For any state $s \in S$, the minimal and maximal probability of reaching G from s over Adv_M are denoted by $Pr_s^{min}(\diamond G)$ and $Pr_s^{max}(\diamond G)$ and are formally defined as:

$$pr_s^{min}(\diamond G) = \inf_{\sigma \in Adv_M} Pr(reach_s^\sigma(G)), \quad (6)$$

$$pr_s^{max}(\diamond G) = \sup_{\sigma \in Adv_M} Pr(reach_s^\sigma(G)) \quad (7)$$

where $Pr(reach_s^\sigma(G))$ is used for the total probability of reaching G from s under the adversary σ and is formally defined:

$$Pr(reach_s^\sigma(G)) = \sum_{\pi \in reach_s^\sigma(G)} Pr^\sigma(\pi) \quad (8)$$

Graph-based computations are used to detect the set of states of an MDP for which the extremal reachability probability is exactly 0 or 1. The properties that relate to the computation of these states are called qualitative reachability properties. On the other hand, the properties related to the computations of reachability probabilities for the remaining states are called quantitative reachability properties.

2.4 Qualitative Reachability Properties

The following sets are defined for the extremal qualitative reachability probabilities:

$$\begin{aligned} S_{min}^0 &= \{s \in S \mid Pr_s^{min}(\diamond G) = 0\}, & S_{min}^1 &= \{s \in S \mid Pr_s^{min}(\diamond G) = 1\}, \\ S_{max}^0 &= \{s \in S \mid Pr_s^{max}(\diamond G) = 0\}, & S_{max}^1 &= \{s \in S \mid Pr_s^{max}(\diamond G) = 1\}. \end{aligned}$$

The computation of these sets are necessary for qualitative verification of MDPs. For quantitative reachability probabilities, there is no need to have these sets but they can improve the precision of the computed values [9]. For the case of extremal expected rewards (where the maximal or minimal expectation of accumulated rewards until reaching a goal state is considered), the computations of the S_{max}^0 and S_{max}^1 are needed to guarantee the convergence of the computed values. Graph-based iterative methods, which only consider the graphical structure of the underlying models are used to compute these sets. Iterative numerical methods are used for the computation of quantitative properties [1, 6]. Algorithm. 1 and Algorithm. 2 describe the standard iterative algorithms for computing the S_{max}^0 and S_{max}^1 [9].

Algorithm 1 The standard algorithm for computing S_{max}^0

Input: MDP $M = (S, s_0, Act, P, G)$

Output: The set $S_{max}^0 = \{s \in S \mid pr_s^{max}(\diamond G) = 0\}$

```

1:  $R := G$ ;
2: repeat
3:    $R' := R$ ;
4:    $R := R' \cup \{s \in S \mid post(s) \in R'\}$ ;
5: until  $R \neq R'$ ;
6: return  $S \setminus R$ ;

```

In each iteration, the Algorithm. 1 adds a state $s \in S/R$ to R if at least one state $s' \in Post(s)$ has been added to R in the previous iteration. The algorithm continues until the case where no new state is added to R . The last set R is the fixed point of the computations and contain all states that can reach to at least one of the goal states. For each $s \in R$ we have $Pr_s^{max}(\diamond G) > 0$. The remaining states (S/R) are those that can not reach to any goal states and correspond to the definition of S_{max}^0 .

For Algorithm. 2, two nested loops are used to compute the S_{max}^1 set. The outer loop starts with S and iteratively removes those states $s \in S$ for which $Pr_s^{max}(G) < 1$. For these outer loop iterations, a sequence of R_i sets are induced where $S = R_0 \subset R_1 \subset \dots \subset R_n = S_{max}^1$. To compute each R_i set the inner loop starts from G (line 6 of Algorithm. 2) and iteratively adds each state $s' \in S$ to R_i if s' can reach to one of the goal states with probability one via the states of R_{i-1} . The remaining states after reaching the fixed point (the states in S/R_n) do

Algorithm 2 The standard algorithm for computing S_{max}^1

Input: MDP $M = (S, s_0, Act, P, G)$

Output: The set $S_{max}^1 = \{s \in S \mid pr_s^{max}(\Diamond G) = 1\}$

```

1:  $R := S$ ;
2: repeat
3:    $R' := R$ ;
4:    $R := G$ ;
5:   repeat
6:      $R'' := R$ ;
7:      $R := R'' \cup \{s \in S \mid \exists \alpha \in Act(s). (post(s, \alpha) \subset R' \wedge post(s, \alpha) \cap R'' \neq \emptyset)\}$ ;
8:   until  $R \neq R''$ ;
9: until  $R \neq R'$ ;
10: return  $R$ ;

```

not belong to S_{max}^1 . The correctness of the standard algorithms for qualitative reachability properties are available in [1, 7].

For an MDP M with $|S|$ states, the time complexity of algorithms 1 and 2 are in $O(|M|)$ and $O(|M| \cdot |S|)$ respectively. In these cases, we suppose that for each state $s \in R'$ the algorithms can determine any states of $Pre(s)$ in a constant time [1]. For this purpose, an standard approach is to restore the information of the model in a backward approach, i.e. for each state $s \in S$ the method should restore the list of states in $Pre(s)$.

The main drawback of the backward approach is its memory overhead which limits it to small models. On the other hand, the forward implementation of these algorithms is proposed and used in PRISM [12]. The forward approach need not any additional memory, but may increase the number of iterations and the running time of the computations. The memory consumption and running time of the forward and backward approaches for the standard algorithms of qualitative verification of MDPs are compared in [16]. In this paper, we only consider the maximal qualitative reachability properties. The standard algorithms for the minimal case can be found in [1, 9]. All proposed techniques of this paper can also be applied to the case of minimal reachability properties.

3 The Proposed Methods for Accelerating Qualitative Verification of MDPs

In this section, we propose three approaches to improve the performance of the standard algorithms for computing qualitative reachability properties in MDPs.

3.1 Reducing Iterations of the Forward Approaches

We use two heuristic techniques to reduce the number of iterations of the forward implementation of the standard algorithms for qualitative verification of

reachability properties in MDPs. Although the idea of these heuristics has been used in the previous works for other classes of properties for MDPs, to the best of our knowledge, they were not applied for computing qualitative reachability properties.

The first heuristic (called h1 for the remaining parts) is to merge separate sets of the standard algorithms to one set. One drawback of the algorithms 1 and 2 (which are proposed in [1, 9]) is that they separate the computed sets in the current iterations from the set of the previous iteration. The Algorithm 1 uses two sets R and R' while it can keep all added states to one set R . In the latter case, any added state in each iteration can be used to add (probably) some other states in the same iteration. In Algorithm 2, the R and R'' of the inner loop can be merged to one set.

The second heuristic (called h2) reduces the total number of iterations using a good state ordering for selecting the remaining states of each algorithm. Several state ordering techniques have been proposed in the previous works for quantitative reachability properties [5] or discounted accumulated rewards [21]. In both cases, the proposed methods use the $Pre(s)$ states of each state s . To avoid the memory overhead of the information of the Pre sets, we use a forward approach for state ordering. The idea of this approach is to consider the graph of the model in a forward manner and perform a breadth-first search on the graph. The visited states of the model (nodes of the related graph) are stored in a list and the iterative methods use the list in reverse order. The algorithm of this method is proposed in Algorithm. 3. This algorithm uses an array *StateOrder* to store the selected states. In each step, it selects a state from the beginning of the array and adds its non-selected successor states to the end of the array. The algorithm terminates when all states of the model have been added to the *StateOrder* array. The main advantage of our proposed state ordering is that it does not need to store any additional information of the model and as a result it does not have any memory overhead. Note that the backward approach does not need to compute the state ordering explicitly. It considers states for adding to the R sets in the right way.

The iterative methods should use the states in the *StateOrder* array in reverse order (from end to the beginning of the array). In general, this state ordering can reduce the number of iterations of the iterative methods because it accelerates the propagation of the related information between the states of the model. This state ordering is used in line 4 of Algorithm. 1 and line 7 of Algorithm. 2 where the algorithms update the R sets in each iteration.

3.2 Disk-based Backward Technique for Qualitative Verification

To compensate the memory overhead of the backward approach, the secondary storage can be used. The idea of this approach is shown in Algorithm. 4. It first uses the MTBDD-based approach to construct the model and directly store the information of the model to the hard disk. Furthermore, it computes the information of the backward graph and loads them into the main memory. This structure does not include the information of transition probabilities and is used

Algorithm 3 Forward method for state ordering

Input: MDP $M = (S, s_0, Act, P, G)$

Output: A state ordering array $Stateorder[]$

```
1:  $l := 0$ ;  
2:  $h := 1$ ;  
3:  $Stateorder[l] := s_0$ ;  
4: while  $l < h$  do  
5:    $s := Stateorder[l]$ ;  
6:   for all  $s_i \in post(s)$  do  
7:     if  $s_i \in Stateorder$  then  
8:        $Stateorder[h] := s_i$ ;  
9:        $h := h + 1$ ;  
10:    end if  
11:  end for  
12: end while  
13: return ;
```

to compute the S_{max}^0 and S_{max}^1 sets. Finally, the information of the remaining states ($S/(S_{max}^0 \cup S_{max}^1)$) will be loaded into the main memory if they are needed for quantitative verification. The main advantage of this approach is avoiding any memory overhead while it uses the backward approach for qualitative verification. However, this approach applied only to those models for which the information of the backward graph can be loaded into the main memory.

Algorithm 4 The Disk-base Approach

Input: An MTBDD representation for an MDP $M = (S, s_0, Act, P, G)$

Output: The sets S_{max}^1 and S_{max}^0

- 1: Store the information of M from MTBDD to the hard disk;
 - 2: Compute the backward graph of M and load it to the main memory;
 - 3: Apply the backward technique for computing the sets S_{max}^1 and S_{max}^0 ;
 - 4: Free the memory of the backward graph;
 - 5: Load the information of M for the remaining states to the main memory;
-

3.3 Using Machine Learning for Qualification Verification of MDPs

Machine learning plays an important role in nowadays life. Classification is a act of categorizing a given set of data into classes. In machine learning, classification is supervised learning in which it infers from the data given to it and makes new observations or classifications based on the pattern extracted from training data [2]. There are many algorithms used in classifying new data. Some types of

classification in machine learning can be summarized as Naive Bayes, Stochastic Gradient Descent, K-Nearest Neighbors, Decision Tree, Random Forest, Artificial Neural Network, Support Vector Machine, and so on.

As the main contribution of this paper, we propose a new approach which uses machine learning techniques to verify the qualitative reachability properties of MDPs. Our technique uses the fact that some parameters define the bound of some variable domains of MDP modules. The size of MDPs for a high-level definition changes according to the values of these parameters. In Fig.1 the initial definition of the *Consensus* model is proposed. This model includes four modules ($N = 4$). Each module contains two variables (*pc1* and *coin1*). A *counter* is defined as a global variable. The model has a parameter (K) which determines the range of the *counter* variable. According to the values of this parameter, we can have some models with different size.

```

1 // COIN FLIPPING PROTOCOL FOR POLYNOMIAL RANDOMIZED CONSENSUS [AH90]
2 // gxn/dxp 20/11/00
3
4 mdp
5 // constants
6 const int N=4;
7 const int K;
8 const int range = 2*(K+1)*N;
9 const int counter_init = (K+1)*N;
10 const int left = N;
11 const int right = 2*(K+1)*N - N;
12 // shared coin
13 global counter : [0..range] init counter_init;
14 module process1
15     // program counter
16     pc1 : [0..3];
17     coin1 : [0..1];
18     // flip coin
19     [] (pc1=0) -> 0.5 : (coin1'=0) & (pc1'=1) + 0.5 : (coin1'=1) & (pc1'=1);

```

Fig. 1. A high-level definition of an MDP model in PRISM environment

In general and for each class of models, we can consider small values for its parameters and have some small MDPs. A standard method can compute the qualitative reachability properties of these small models. As a result, the set S of state of a model are classified into the S_{max}^0 , S_{max}^1 , and $S_{max}^? = S / (S_{max}^0 \cup S_{max}^1)$ sets. We use the small models for training a classifier. Furthermore, it is used to classify the state space S of a large model to its S_{max}^0 , S_{max}^1 , and $S_{max}^?$ sets. We consider the variables and parameters of each model as its properties and its states as the samples for training. Also, for each variable with parametric domain (like the *counter* variable in Fig.1), we consider a property as the difference between its domain bound and its values. This additional property helps the classifier to improve its performance.

4 Experimental Results

To show the feasibility and applicability of the proposed approaches, we consider several test case models. These test cases are selected from the PRISM standard case studies and are widely used in the literature [9]. For the forward approach, we implement our improvements in the PRISM model checker. We use its sparse engine, which is implemented in C. We use a machine with a Core-i7 Intel processor with 8GB of RAM. In Table 1, the experiments for computing S_{min}^0 and S_{max}^0 sets are demonstrated. The first column of the table presents the model’s name. For *Consensus*, *Zeroconf*, and *Wlan* classes, we consider a maximal reachability property and for the *Firewire* class, we consider a minimal reachability property. More information about these classes are available in [12]. The MDP size of each model is the number of its states and transitions.

We consider the running time and the number of iterations of Algorithm. 1 for the MTBDD-based method as is used in PRISM. We also demonstrate the running time of the sparse implementation of this algorithm. For our proposed heuristics, we report the running time and the number of iterations of the forward method with these heuristics. The running time in all tables are in seconds.

Table 1. Case study models, number of iterations and running times for computing S_{min}^0 and S_{max}^0 sets

Model (parameters)	Parameter values	MDP Size	MTBDD		sparse	forward with h1		forward with h2	
			time	iters	time	time	iters	time	iters
Consensus	6 , 18	604K	2.25	979	1.1	.47	511	.01	7
	8 , 18	2378K	10.9	1305	6.3	4.3	681	.1	8
	N,K 10 , 10	4725K	14.8	911	7.5	7.1	477	.3	9
Zeroconf	10	9787K	6	140	3.7	1.6	98	2.14	12
	14	14.4M	7.5	156	3.9	2.14	110	4.9	12
	K 18	17.8M	10.1	172	8.6	122	4.9	12	4.4
e	4,2500	7052K	18.4	207	.7	.26	76	.8	65
Wlan (K,ttm)	5, 1000	8905K	10.4	399	1.24	.44	140	1.39	129
	6, 200	18264K	17	783	2.2	.73	268	2	257
firewire (delay, deadline)	12,600	28.35M	30	373	13.6	12.4	368	3.1	5
	30,400	115M	161	409	52.7	48	404	9.7	4
	30,600	227.7M	345	409	110.3	100.5	404	25.3	4

In Table. 2, we show the running time for the standard iterative method and our heuristics for computing the S_{min}^1 and S_{max}^1 sets. For Disk-based technique, the running times include the time for writing a model in the secondary disk, constructing the backward graph, computing qualitative reachability properties using the backward graph, and finally loading the information of the remaining part of each model (for the $S^?$ sets) to the main memory. For the case of S^0 sets, all running times are less than 1 second and we do not separate their running times.

Table 2. Case study models, number of iterations and running times for computing S_{min}^1 and S_{max}^1 sets

Model (parameters)	Parameter values	MTBDD		sparse time	forward with h1		forward with h2		Disk-based time
		time	iters		time	iters	time	iters	
Consensus (N,K)	6, 18	323	94.6K	141	85	56.5K	2.6	1118	7.2
	8, 18	1513	169K	1934	1359	101K	35.3	1788	17.7
	10, 10	1738	88K	1767	1551	52.5K	113	1486	24
Zeroconf (K)	10	121	2357	104	30.1	1200	66.1	213	4.9
	14	184.3	2525	74.9	36.6	1385	52.4	209	5.1
	18	128.4	2665	97.9	58.6	1481	107.8	192	6.5
s Wlan (K,ttm)	4 , 2500	58.3	414	9.2	3.3	226	3.1	65	2.2
	5, 1000	30.8	798	17.2	5.5	418	4.1	206	2.7
firewire (delay, deadline)	6, 200	39.1	1566	29.2	9.1	802	8	256	2.9
	12,600	33	261	11.2	9.7	255	.96	4	6.3
	30,400	74.2	169	14.3	11.4	156	2.1	3	17.9
	30,600	189	253	54.6	51.5	244	5.2	4	31.4

The results of Table 1 and 2 show that our proposed heuristics for the forward implementation of the standard algorithms improves their performance for computing qualitative reachability properties of MDPs. The best results are for the Consensus and *firewire* cases. For the *wlan* and *zeroconf* models, our heuristics reduce the number of iterations by one or two orders of magnitude. In most cases, the Disk-based method outperforms the others. Note that this approach is more useful for large models, where the information of a model cannot be loaded to the main memory.

To apply machine learning for computing qualitative reachability properties of MDPs, we use Scikit-learn package of Python. For each class of models, we consider two or three small models for training and use decision tree classifier of Python. For each training MDP samples, PRISM is used to separate the state to the S_{max}^1 , S_{max}^0 and S_{max}^2 classes. We use the *exportstates* PRISM command to store the state-property information of states to related files. The inputs to the training phase are the state-separated and state-property files. To test the precision of this technique, we consider several test cases for each class of models. The results of this technique are proposed in Table. 3.

To compare the running time of the proposed methods for computing the S_{max}^1 sets we consider several models of the *Consensus* example with N=6 and different values for the K parameter in range [20,100]. The results are proposed in Fig. 2 where the horizontal axis shows the value of K and the vertical axis shows the running time in logarithmic mode. The results show that our proposed heuristics reduce the running times by at least two orders of magnitude.

5 Conclusion and future work

In this paper, we propose several techniques to improve the performance of the iterative computations for the qualitative reachability properties of MDPs. We

Table 3. Experimental results of the proposed machine learning approach for computing S_{max}^0 and S_{max}^1 sets

Model (parameters)	Param value	Sample parameters	Reading samples time	Training time	Test parameter	test time	Precision iters	False detects
Consensus	6	K=3,4	.9	.1	K = 50	82	100%	2
N	8	K=3,4	2.4	.27	K = 35	17.1	100%	2
Zeroconf	-	K=2,3	6.2	.62	K = 14	2.14	99.8%	26,070
Wlan (K)	5	ttm=50,100	43	5.9	900	18.7	100%	0
	6	ttm=50,100	89.5	11.3	600	26.5	100%	0
firewire (delay)	12	ddl=200,250	7.2	2.2	ddl=800	57	100%	0
	30	ddl=200,250	48.4	11	ddl=600	145.8	100%	0

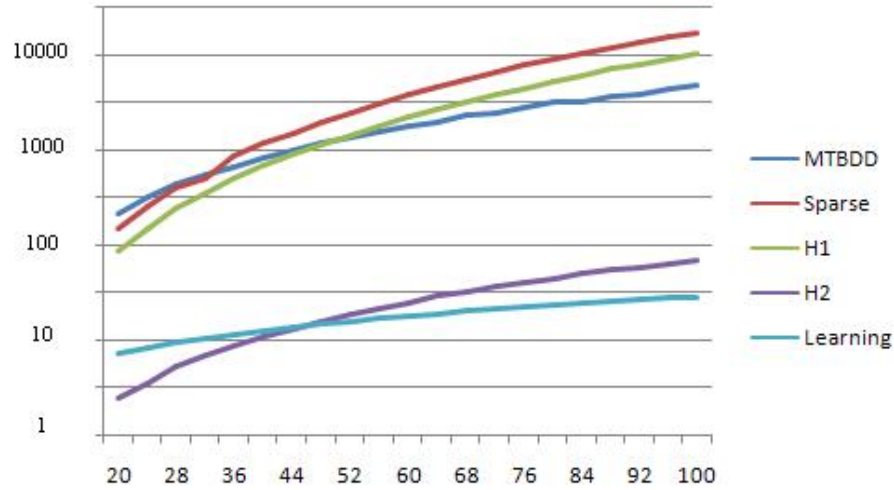


Fig. 2. The running times for computing S_{max}^1 sets for the *Consensus* case studies.

first propose two heuristics for the forward implementation of the standard algorithms. The running times of our experiments show promising results for these heuristics. Because of the memory limitation of the explicit methods, we propose a disk-based method to save memory for graph-based computations. As the main contribution, we propose a method using machine learning to classify the state space of a model to the related classes. The experiments show promising results for this technique. For future works, we plan to extend our machine learning method to other problems of probabilistic model checking. As an example, this technique can be used to approximate the optimal policy of a large MDP model, which can be used for improving the current techniques for statistical model checking.

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Machine Learning Methods in Medicine Diagnostics Problem

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Abstract. Medical service improvement has always been a life topical problem. To decide it, we must continuously raise the competency of doctors on the one hand and it is necessary to develop new methods and approaches which could help take decisions concerning diagnostics (classification) of patient health conditions and concerning patient’s further treatment.

At the paper the machine learning methods for patient health condition classification were considered. These methods were Naive Bayes Classifier, Linear Classifier, Support-vector machine, K-nearest Neighbor Classifier, Logistic Regression, Decision Tree Classifier, Random Forest Classifier, Ada Boost Classifier and Artificial Neural Network. A radial basis network was chosen from the variety of artificial neural system architecture to solve classification tasks.

The problem of patient health conditions classification was considered for two sets of laboratory research results: on liver diseases and on urological diseases.

Confusion matrixes and ROC-curves were taken to estimate classification quality of patient health conditions with above-mentioned methods.

Keywords: medicine diagnostic, machine learning, artificial neural network, ROC-curve, confusion matrix.

1 Classification Methods of the Complex Dynamic System State

Origin and evolution of errors in complex systems are the complex dynamic process. Experts cannot always predict their origin exactly and define the type of failure. However, bringing the system back to normal mode is paramount importance. Control and prediction over the state of complex dynamic systems help specialists take effective measures. Thus, great attention is paid to the classification of complex system states. Today, we have many publications describing methods of settling the problem

of complex system states classification. We'll consider the ones which are mostly frequently viewed.

Naïve Bayes Classifier is a simple probabilistic classifier, which relies on applying the Bayes theorem with 'naïve' assumption of mutual sign independence. It applies to the simplest models of the Bayes network. Naïve Bayes method developments started in the distant 1960s and are still a popular method of text categorization (e.g. a scientific text, a fiction literature text, spam etc.) [1]. This method is also applied for the automated medical diagnostics [2].

Advantages of the method:

- in the little data sets, it can achieve better results than other classifiers because of low tendency to retraining;
- linear scalability on the quantity of possible signs; a slight renovation on new educational data is also possible;
- the method can process overlooked data by retraining and forecasting;
- despite the fact that the assumption about sign independence is often false, the Bayes classifier can independently estimate each sign class; it makes it possible to avoid the problem of large dimension [3].

Disadvantages of the method:

- Naïve Bayes evidently assumes that all the signs are mutually independent, which is almost impossible in reality;
- if the variable has the textual data set category which was not observable in the learning data set, the model will set the probability 0 and won't be able to make forecasting;
- quality of work is sensitive to the class distribution representativeness in the total package.

Linear classifier is a method of machine learning, which takes decisions about the class by relying on the linear behavior combination values; they are usually represented as a vector. Subdividing into classes in the multidimensional space can be made by dividing with a straight or n-dimensional plane. These classifiers work well for practical problems, e.g. for document classification. Moreover, the method can achieve the non-linear classifier results within less time on learning and use [4].

Advantages of the method:

- linear classifier is often used when the speed of classification matters, since it is the fastest classifier, especially if the input vector is very big;
- fast method realization and low requirements for operative memory and the central processor.

Disadvantage of the method: linear character of the method doesn't make it possible to define the class exactly when it is impossible to clearly discriminate between the classes, as data distribution is usually mixed and demands non-linear separation.

Support-vector machine (SVM) is a controlled learning model with a tutor, and usually used for classification and regression analysis. The method was proposed by

Vapnik V. and Chervoneniks A. in 1963. Allowing for the set of educational examples, each of which earlier attributed to one of the two categories, the learning algorithm SVM builds a model, which can assign a new example to a specific category. The SVM model is a presentation of examples as points in space, represented so that the examples of separate categories are divided into discrete highest possible intervals. Then, new examples are represented in the same space; they are assumed to be in the category which is based on that side of the space where they belong [5].

SVM can be used for solving various real tasks:

- for categorization of a text and hypertext, since it diminishes the need in marked learning data [6];
- for image classification [7];
- for cursive identification [6];
- in biology and other sciences. It was used for protein classification and gave 90% classification correctness [6].

Advantages of the method:

- retraining problem is not so important as with other methods;
- SVM doesn't heavily depend on computer memory;
- SVM works rather effectively in the cases when the task dimension exceeds the number of examples.

Disadvantages of the method [8]:

- the methods are characterized by high calculation complexity. As compared to other simple methods (K-NN, Decision Tree, Naïve Bayes Classifier), the method requires more time for learning;
- the major problem is the choice of the most appropriate central function. Various central functions give different results for each data set;
- SVM has bad results in the case of noise present (target classes have no distinct partition boundary).

Relevance Vector Machine (RVM) is a method of machine learning, which uses a Bayes conclusion to obtain decisions on the principle of economy for regressive and probabilistic classification [9].

Advantages of the method:

- RVM has the identical functional form with SVM, but it provides probabilistic classification;
- Bayes RVM base makes it possible to avoid SVM independent parameter sets, which generally require post-optimization, based on cross check.

The main disadvantage of the method is that it employs a learning method, resembling expectance maximization, so it may give a local extremum. At the same time, standard algorithms on the basis of successive minimum, used in SVM, will find global extremum.

K-Nearest Neighbor Classifier (k-NN) is a nonparametric method used for classification and regression. In both cases, the input consists of k nearest educational examples in a function space. In B classification, k-NN output is a notion of class. The object is classified on the majority vote with its nearest neighbors. At this time, the object is assigned to the class which prevails over its nearest neighbors (k is a whole number, as a rule, small). If k equals 1, the object is simply assigned to the class of this nearest exclusive neighbor [10].

Neighbors are taken from the set of objects, for which the class (for k-NN classification) or object property value (for k-NN regression) is known. It is considered to be the learning algorithm set, though a distinct preparation step is not needed [10].

The specific feature of k-NN method is that it is not sensitive to the data local structure [10].

Advantages of the method:

- absence of the education step. The method saves the learning data set and learns only in real time forecasting. It makes the algorithm k-NN much faster than other ones which require learning, for example, SVM, Linear Regression etc.;
- new data are easy to add because the k-NN algorithm doesn't require preparation; this won't influence the method accuracy;
- k-NN is very simple to realize, it needs only two parameters: the number of classes k and the distance function (e.g. Euclidean, Manhattan etc.).

Disadvantages of the method:

- it works poorly with large data sets. In large data sets, the complexity of calculating the distance between the new point and each existing point is enormous; it worsens algorithm efficiency;
- it requires function scaling (standardization and normalization) before applying the k-NN algorithm to any data set. If we don't do this, k-NN may generate wrong forecasts;
- it is sensitive to noisy data, absence of values. It is necessary to inscribe omitted values or erase remainders manually.

Logistic regression is a statistical model, which uses the logistic function for modelling binary dependent variable in its basic form. The logistic regression measures interdependence between categorically dependent variable and one or several independent variables by evaluating probabilities with a logarithmic function [11].

Logistic regression can be considered as a special case of generalized linear model and, thus, similar to the linear regression. However, the logistic regression model is based on the assumptions of dependent and independent variable interdependence. The key differences between these models can be seen in the following two logistic regression peculiarities. Firstly, conditional distribution ($y|x$) is a Bernoulli distribution, but not gaussian, because the dependence curve is binary. Secondly, the forecast values are probable and, thus, are limited (0,1) through a logistic distribution function because logistic regression assumes concrete result probability, but not pure results.

Advantages of the method [12]:

- logistic regression works well when the data set is linearly separable (which is common for k-NN and Linear Regression);
- logistic regression has less tendency for retraining, but retraining can appear in big dimension data sets: regularization methods are generally used to solve this problem;
- logistic regression can forecast not only the final class, but show the interconnection between input data and a resulting class;
- logistic regression method is simple in realization, interpreting, and is effective in learning.

Disadvantages of the method [12]:

- the principal limitation is the assumption about linearity between the dependent variable and independent variables:
- if the quantity of observations is less than the quantity of variables, the logistic regression shouldn't be used because this can lead to overlearning;
- logistic regression can be used just to forecast discrete functions. Therefore, the dependent logistic regression variable is limited by a discrete number set.

Decision Tree Classifier [13] is the machine learning method, which uses a decision tree model for classification. The tree model, where the target variable can take a discrete value set, is also called the classification tree. In these tree structures, the leaves represent the class marks and the branches – the combination of signs leading to these class marks. The decision trees, where the target variable can take permanent values (real numbers, as a rule) are called the regression trees.

Advantages of the method:

- decision tree is simple to understand, is easy to represent graphically [13];
- it is capable of processing numerical and categorical data as well;
- it requires a small data preparation. Other methods often demand data normalization. Fictitious variables are not necessary here because the trees can work with qualitative forecasts;
- possibility for checking the models by statistic tests. It makes it possible to take into account the model reliability;
- a non-statistical approach, which doesn't foresee assumptions concerning learning data and forecast remainders e. g. no assumptions as to distribution, independence or constant dispersion;
- it works well with big data sets;
- the mirror of human decision taking is closer than other approaches [13]. This may be useful when modelling human decisions / behavior.

Disadvantages of the method:

- the trees can be very unstable. A little change of learning data can lead to the change of a tree and consequently of final forecasts [13];
- it is known that the problem of studying the decision optimal tree is NP-complete in several optimality aspects and even for simple conceptions [14]. Thus, the learn-

ing algorithms of the decision practical tree are based on the heuristic, such as a greedy algorithm, where the locally optimal decisions are taken at every unit. Such algorithms cannot guarantee obtaining optimal decisions on the whole decision tree. To decrease the locally optimum greedy algorithm, e. g. the double information distance tree was suggested [15];

- for the data including categorical variables with different level quantities, the decision tree information gain is biased in favor of big level attributes. However, the problem of biased choice is resolved, e.g. by a conditional conclusion approach.

Random Forest Classifier is an ensemble method of classification, regression, which works by constructing many decision trees during learning and withdrawal of the class which is a regime class (classification) or average forecast (regression) of separate trees [16, 17]. The first algorithm of random decision forests was created by Tin Kam Ho [16] on the basis other random subspace method [17], which, as formulated by Ho, is the means of realizing "stochastic discrimination" approach to the classification proposed by Eugene Kleinberg [18].

Advantages of the method:

- random forest is based on the stacking algorithm and uses the ensemble learning technics;
- random forest works well both with categorical and persistent variables;
- random forest can automatically process missing values;
- it doesn't demand function scaling (standardization and normalization), since this method demands the approach based on rules instead of calculating distance;
- the random forest algorithm is stable.

Disadvantages of the method:

- complexity. Random forest creates many trees (unlike only one tree in the case of a decision tree) and comprises their results: e.g. on default it creates 100 trees in the sklearn Python library. This method demands much more computing power and resources;
- longer learning time: random forests require much more time for preparation compared to decision trees, since they generate many trees (instead one tree in the case of a decision tree) and take decision by a majority of votes.

AdaBoost Classifier is the machine learning meta-algorithm formulated by Yoav Freund and Robert Shapiro. It can be used with many other classification algorithms for productivity improvement. The output of other classification algorithms (weak classifiers) is assembled into a weighted sum, which is a finite output of the accelerated classifier. AdaBoost is adaptable: weak classifiers are adjusted in favor of those cases which were classified earlier. AdaBoost is not very sensitive to the data noise. In some tasks it can be less sensitive to the retraining problem, than other learning algorithms.

Each classification algorithm usually corresponds to some types of tasks better than others and, as a rule, has great number of various parameters and configurations, which must be corrected before achieving optimal data set productivity. AdaBoost,

alongside with decision trees as weak classifiers, are often called the best classifier [19]. When using decision trees, the information collected in every phase of the AdaBoost algorithm about the relative rigidity of each learning pattern is put to the tree building algorithm, so that the later trees, as a rule, are concentrated on more important examples to classify.

Advantages of the method:

- weak classifiers for cascading are easy to use;
- various classification algorithms can be used as weak classifiers;
- AdaBoost has high accuracy;
- AdaBoost isn't sensitive to the data noise.

Disadvantages of the method:

- quantity of AdaBoost iterations are also determined by the quantity of weak classifiers, which can be defined with cross check;
- data imbalance results in lower classification accuracy;
- learning takes longer time.

Artificial Neural Network (ANN) is a computing system, which is inspired by biological neural networks. Such systems 'learn' to decide tasks, considering examples and, as a rule, are not programmed to perform concrete tasks.

ANN is based on the combination of coupled units or packs called artificial neurons, which freely model neurons in the biological brain.

The primary aim of ANN approach consisted in solving problems as the human brain does. However, in due course, ANN application shifted to deciding variety of tasks, including computer vision, speech recognition, machine translation, filtering in the social network, game boards and video-games, medical diagnosis, and even in schools which are traditionally considered to be human activities (e.g. painting) [20].

Advantages of the method [21]:

- information storage on the whole network. Disappearance of some information fragments in one place don't impede the network function;
- ability to work with insufficient knowledge;
- fault tolerance: damage of one or several ANN cells won't impede the data output;
- possibility to learn: artificial neural networks study events and take decisions, using such events;
- possibility of parallel processing.

Disadvantages of the method [21]:

- estimation of proper network structure: there aren't concrete rules to define structure of artificial neural networks. The network structure is chosen by relying on the practical experience or trial-and-error method;
- ANN can work only with numerical data. The data must be converted into numerical values before introducing into ANN.

To solve the classifying problem of the patient's state the Radial Basis Function Network was chosen. In this Network a multiple logistic regression was used [22]. This allows classification by more than two classes. And as the learning algorithm the stochastic approximation algorithm with deep learning elements based on the ravine conjugate gradient method was used. This Radial Basis Function Network was independently implemented by the authors in the "ROD&IDS[®]" computer decision support system, designed to solve the problem of diagnosing, classifying and optimizing systems and processes.

2 Problem Statement

Let the condition multidimensional matrix be known $X = \{x_{i,j}\}$, ($i = 1..I, j = 1..J$), where I is the quantity of checked patients and J is the quantity of state characteristics (variable) to be measured. The majority of the examined methods require normalizing input data; centering and normalizing are done according to the formula

$$x_{i,j}^0 = (x_{i,j} - \langle X_j \rangle) / \sigma_j,$$

where $\langle X_j \rangle$ is the average of j-state attribute, σ_j is its quadratic mean deviation. The task of building a classification model of the patient state: the vector function is given

by a set of learning couples $\left(\vec{X}^{(0)}, \vec{d} \right)_p$, $p=1..P$, with input dimension vectors H_0 and output dimension H_{k+1} . It is necessary to build the mathematical vector function $\vec{Y}^{(K+1)} \left(\vec{X}^{(0)} \right)$ for the input data approximation.

We formulate the classification problem. Let \vec{X}^* be the variable vector, which describes the state of a patient and M – multitude of scenarios (possible state classes). According to the values of \vec{X}^* vector, the current state is related to one of the multitudes R_m , where $m=0..M-1$. It is necessary to find such m -scenario, for which the maximal distribution density of the conditional appearance probability in m -scenario:

$$\exists! m^* \in C_m \left(\rho \left(\vec{X}_m^* \middle| R_m \right) \right) (m = 0..M-1) : \rho \left(\vec{X}_m^* \middle| R_m \right) \rightarrow \max,$$

where $C_m \left(\rho \left(\vec{X}_m^* \middle| R_m \right) \right)$ is the multitude of m -indices of distribution density of the conditional appearance probability in m -scenario.

Let us consider the medical-biological system. The final state of patients and a set of parameters describing it are characteristic for each medical treatment stage. Take the hypothesis that the state of a patient is definitely defined by this set of parameters. Therefore, the task of checking health state is reduced to the task of classification of patient status variables. Let's examine the application of above-mentioned methods for solving the task of patient state variable classification. We'll estimate and compare the quality of classification by these methods.

3 Methods of Estimating Classification Quality

A confusion matrix is used in machine learning to solve classification problems for productivity visualization and algorithm work quality (usually learning with a teacher) [23]. Each line of the fault matrix is a copy in a forecast class and each column is a copy in a real class 9 (or vice versa). The matrix name comes from the fact that it helps vividly see whether the resultant classes are mixed or not, i.e. whether the one class is defined as the other.

We consider fault matrix building for the problem of binary classification. Let the classification result be designated as positive (p) and negative (n). The binary classifier has four possible results. If the classification result is p and the actual meaning is p, then the result is called real positive (TP). If the classification result is p and the actual meaning is n, then the result is called confusion (fault) positive (FP). Similarly, the result is called real negative (TN), if the classification result and real meaning are n, and it is called confusion negative (FN) if the classification result is n, but the real meaning is p.

Suppose we carried out an experiment for P positive copies and N negative cases. The classification results can be summarized in in the fault matrix, shown in Fig. 1.

ROC curves are also used to estimate classification quality. An ROC curve is a diagram which helps estimate binary classification quality. It is defined by the correlation between the quantity of objects from the total amount of sign media classified as true sign media (classification algorithm sensitivity) and the number of objects from the total amount of sign media with no sign, classified mistakenly as sign media [24].

		True condition			
		Condition positive	Condition negative	Prevalence $= \frac{\sum \text{Condition positive}}{\sum \text{Total population}}$	Accuracy (ACC) = $\frac{\sum \text{True positive} + \sum \text{True negative}}{\sum \text{Total population}}$
Predicted condition	Predicted condition positive	True positive	False positive, Type I error	Positive predictive value (PPV), Precision = $\frac{\sum \text{True positive}}{\sum \text{Predicted condition positive}}$	False discovery rate (FDR) = $\frac{\sum \text{False positive}}{\sum \text{Predicted condition positive}}$
	Predicted condition negative	False negative, Type II error	True negative	False omission rate (FOR) = $\frac{\sum \text{False negative}}{\sum \text{Predicted condition negative}}$	Negative predictive value (NPV) = $\frac{\sum \text{True negative}}{\sum \text{Predicted condition negative}}$
		True positive rate (TPR), Recall, Sensitivity, probability of detection, Power $= \frac{\sum \text{True positive}}{\sum \text{Condition positive}}$	False positive rate (FPR), Fall-out, probability of false alarm $= \frac{\sum \text{False positive}}{\sum \text{Condition negative}}$	Positive likelihood ratio (LR+) $= \frac{\text{TPR}}{\text{FPR}}$	Diagnostic odds ratio (DOR) $= \frac{\text{LR+}}{\text{LR-}}$
		False negative rate (FNR), Miss rate $= \frac{\sum \text{False negative}}{\sum \text{Condition positive}}$	Specificity (SPC), Selectivity, True negative rate (TNR) $= \frac{\sum \text{True negative}}{\sum \text{Condition negative}}$	Negative likelihood ratio (LR-) $= \frac{\text{FNR}}{\text{TNR}}$	

Fig. 1. Possible meanings defined by the confusion matrix.

ROC quantitative interpretation gives an AUC indicator; it is the area limited by a ROC curve and the axis, which equals to fault positive classifications. The higher AUC indicator the better a classifier works. The value less than 0.5 shows that the

classifier acts vice-versa: in the case of positive classifications it calls them negative, and the negative classification is represented as positive [23]. There exist many classifications of ROC curves for classification estimations according to more than 2 classes and also the ones which with a diagram help estimate the drawbacks of the current classification modes. Fig. 2 shows two diagrams, which characterize work of two classification algorithms.

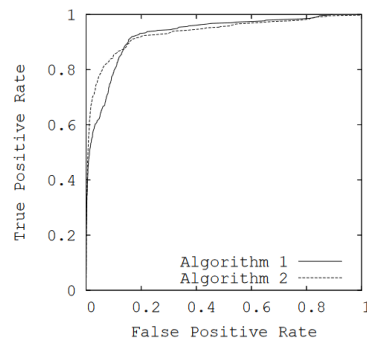


Fig. 2. ROC-curves which compare work of two algorithms.

The diagram clearly shows which class was better recognized as apposite, which is suitable for model classification adjustment.

4 Methods Comparison for Medical-Biological System State Classification

Let's examine a patient within a period of medical treatment. To make the diagnosis more accurate, we formulate the problem of patient state classification: to define the current state of the patient (healthy or sick) according to the laboratory research records and primary health examination. The problem was solved for two data sets on liver disease and urological disease. These data provided by the Department of Infectious, Pediatric and Oncological Urology, Kharkiv Medical Academy of Postgraduate Education.

The urological disease sampling contained information for 40 patients. These data were divided into learning (30) patients and testing (10 patients). The information for one patient consisted of 47 estimated characteristics with the values of three types: real, Boolean and enumerated numbers.

The liver disease sampling consisted of the information for 590 patients. Learning sampling was taken from 420 patients, testing sampling – from 170 patients. The information for one patient consisted of 10 estimated characteristics with the values of three types: real, Boolean and enumerated numbers.

To solve classification problems, we used Naïve Bayes Classifier, K-nearest Neighbor Classifier, Logistic Regression, Random Forest Classifier, Ada Boost Classifier and Radial Basis Function Network.

Learning and testing problems made it possible to error matrices and ROC-curves for classification quality analysis. For example, on fig. 3 and 4 the error matrices and ROC-curves of the Naïve Bayes Classifier results are presented.

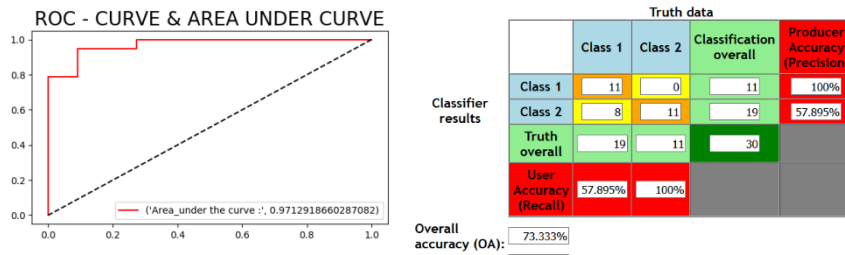


Fig. 3. ROC-curve and confusion matrix based on the method Naïve Bayes Classifier for patients with urological diseases.

For the first data set on urological diseases, Logistic Regression, AdaBoost Classifier and Radial Basis Function Network give 100% classification accuracy with ROC AUC=1, the Random Forest Classifier method – 96.6% classification accuracy and ROC AUC=1, Naïve Bayes Classifier – 73.3% classification accuracy and ROC AUC=0.97, K-nearest Neighbor Classifier – 80% classification accuracy with ROC AUC=0.82.

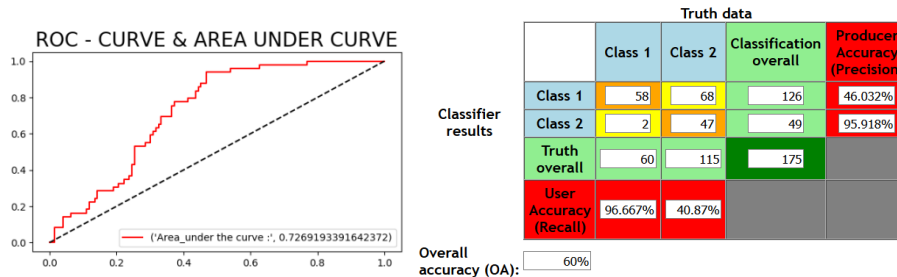


Fig. 4. ROC-curve and confusion matrix based on the method of Naïve Bayes Classifier for patients with liver diseases.

The second data set for liver diseases cardinally differs from the first in dimensions (4 times less attributes, but 18 times more recordings). For classification, we used the same methods. The obtained results are: Naïve Bayes Classifier method – 60% classification accuracy and ROC AUC=0.73, K-nearest Neighbor Classifier – 81.7% classification accuracy and ROC AUC=0.898, Logistic Regression – 80.98% classification accuracy and ROC AUC=0.787, Random Forest Classifier – 98.86% classification accuracy and ROC AUC=0.99, Ada Boost Classifier – 85.7% classification accuracy

and ROC AUC=0.94, Radial Basis Function Network – 80.56% classification accuracy and ROC AUC=0.801.

Thus, the most qualitative data classification about the state of patients' status was given by Random Forest Classifier method, it showed high accuracy and ROC AUC indicator for both data sets.

5 Conclusions

Diagnosing complex dynamic system states, e. g. medical-biological system (patient), faces the problems of system state classification. The work studied methods of deciding classification tasks, such as Naïve Bayes Classifier, K-nearest Neighbor Classifier, Logistic Regression, Random Forest Classifier, Ada Boost Classifier and Artificial Neural Network (Radial Basis Function Network architecture). Confusion matrices and ROC-curves were taken for quality classification estimation.

The Radial Basis Function Network differs from the classical one in that it uses multivariate logistic regression and a recurrent learning algorithm with deep learning elements. The Network application allows to not depend on the data type and expert opinion during making decisions.

As an example, we considered two data sets, which characterized the state of patients with liver and urological diseases. As a result, all the methods gave classification accuracy more than 80% except for Naïve Bayes Classifier. Radial Basis Function Network showed the best classification quality with 100% accuracy for urological diseases and the Random Forest Classifier method showed the best classification quality with 98.86% for liver diseases.

Further, we are planning to test the methods which showed the best classification for other data sets with different dimensions. The authors are also working out a modification of the method by using Radial Basis Function Network to improve its accuracy for various input data.

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Methodology for the selection of an optimal location of Remote Tower Centre

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Abstract. According to the National transport strategy of Ukraine for the period up to 2030, one of the tasks is to ensure consistent and coherent development of regional airports of Ukraine and the consequent development of the Ukrainian air transportation network. One of the ways to achieve this is to deploy a remote tower concept in small regional airports of Ukraine. The main change introduced by the remote tower concept compared to the conventional air traffic service (ATS) provided from a local tower is that the aerodrome control tower will be provided from a remote location and air traffic control and aerodrome flight information service officers (ATCO/AFISO) do not have to be physically present at the airport. The provision of remote ATS requires a continuous exchange of information between the infrastructure at the airport side and a Remote Tower Module (RTM) to ensure that the data received by ATCO/AFISO can be used to provide safe and orderly control of traffic. The aim of this article is to create a methodology for the selection of an optimal location of Remote Tower Centres (RTC) using a method of gradient descent for finding optimal locations of RTCs to reduce the latency of data transmission. The optimal location of RTC will contribute to the reliability of the ATS systems by balancing safety and economic efficiency brought by the implementation of a remote tower concept.

Keywords: aerodrome flight information service, airport, air traffic control, air traffic management, gradient descent method, regional airport, remote tower centre, remote tower concept.

1 Introduction

A small amount of flights in small regional airports is a common issue for many countries around the world. Most of the small airports struggle to break even, however at the same time provide necessary points of access to remote locations and contribute to the local economic development [1; 2].

According to the National transport strategy of Ukraine for the period up to 2030, one of the tasks for this period is to ensure consistent development of regional airports

of Ukraine and consequently the development of the air transportation network of Ukraine. One of the ways to achieve that is to decrease the costs of air transportation for airspace users and attract more flight to regional airports with lower costs [3].

The cost of a flight for an airspace user (e.g. airline) in the world and also Ukraine consists of fuel, maintenance costs, airport charges, air navigation service (ANS) costs [4; 5; 6].

Reduction in one of them could lead to the reduction of the costs of air transportation for the airspace user and make the flight to a certain airport more effective. In aviation is always significant attention is paid to Safety Management [7; 8].

In determining an acceptable level of safety, it is necessary to consider such factors as the level of risk that applies the cost/benefits of improvements to the system, public expectations on the safety of the aviation industry, that is, ensuring a balance between safety and economical effectiveness when the flights' intensity and the corresponding workload on operators and maintenance equipment change [9 -12].

Reduction in air navigation service costs can be achieved through the optimization of operational costs and enhancement of operational efficiency of the air navigation service provider (ANSP). A number of Single European Sky ATM Research (SESAR) solutions have been developed to enhance the current airport operations and provision of air traffic services (ATS) at an airport with an aim of improving operational efficiency [13].

A few of the SESAR solutions describe the implementation of a remote tower concept in different operating environments. The concept offers a possibility to improve the efficiency of operations and enhance safety at airports where maintenance or building of a conventional air traffic service tower is too expensive. The remote tower concept has been successfully validated by the SESAR programme and deployed in a number of countries [14].

2 Analysis of the current airport operations in Ukraine

At the moment, air traffic services at Ukrainian airports are provided from conventional ATS towers in accordance with ICAO Doc 4444, 9426 and EUROCONTROL Manual for Aerodrome Flight Information Service (AFIS) and internal manuals of ANSP by air traffic controllers or aerodrome flight information service officers that are located locally at the airport [4; 8; 15].

The responsibility of the aerodrome control tower is to provide information and clearance to the flight crew to ensure safe, orderly, and efficient flow of air traffic at the aerodrome and in the vicinity of it. Air traffic control officers (ATCO)s at the aerodrome control tower should continuously monitor all flight operations on the aerodrome and its vicinity as well as vehicles and personnel on the manoeuvring area through visual observation (augmented by ATS surveillance system in low visibility conditions if available).

Functions of the aerodrome control tower may be performed by different control roles such as:

- aerodrome controller – responsible for operations on the runway and in the area of responsibility (AoR) of the aerodrome control tower;

- ground controller – responsible for traffic on the manoeuvring area (with the exception of runways);
- clearance delivery position – responsible for delivery of start-up and air traffic control clearance to departing instrument flight rule (IFR) flights [4].

The main operational requirements for the aerodrome control tower to ensure safe and efficient control of air traffic on and in the vicinity of the aerodrome are:

- The tower must permit the ATCO to visually observe and survey the portions of the aerodrome and its vicinity over which s/he has the control;
- The tower must be equipped to permit the controller rapid and reliable communications with aircraft with which s/he is concerned [8].

The airport network of Ukraine consists of 29 certified airports, 16 of which are capable of serving international flights (equipped with international checkpoints). Airports of Odesa, Kyiv (Boryspil), Kyiv (Zhuliany), Kharkiv, Dnipro and Lviv are considered as strategic airports, however, the main airport of Ukraine is Kyiv Boryspil airport that serves over 67% of the total annual passenger flow of Ukraine and handles more than 44% of all instrument flight rule (IFR) flights in Ukraine [14].

The air traffic control service is provided at 17 airports of Ukraine (those are – Kyiv (Boryspil), Kyiv (Zhuliany), Kharkiv, Chernivtsi, Kropyvnytskyi, Kryvyi Rih, Dnipro, Lviv, Odesa, Poltava, Kherson, Rivne, Sumy, Vinnytsia, Zaporizhzhia, Uzhorod, Ivano-Frankivsk). The AFIS is provided at 4 other airports (Mykolaiv, Cherkasy, Kaniv and Ternopil). Almost half of the traffic is handled by the major airport of Ukraine – Kyiv (Boryspil) while the rest is spread among other airports (Figure 1).

As can be seen from Fig. 1 most of the regional airports in the observation period provided regular air traffic service only to a few flights per day (on average 4 flights per day).

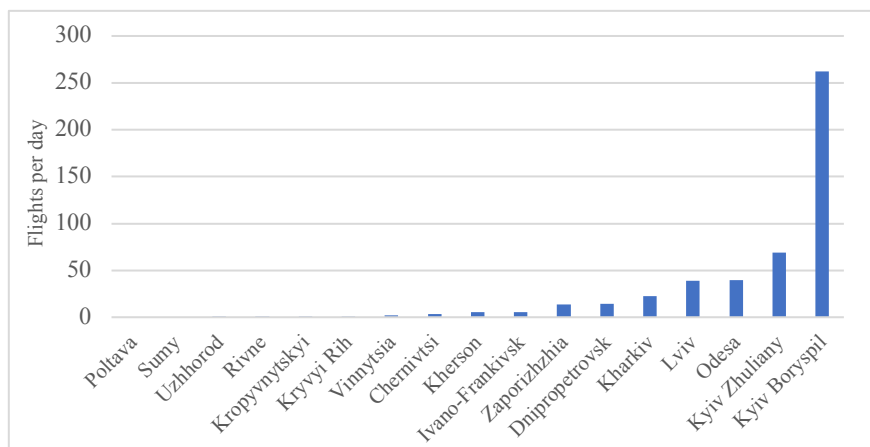


Fig. 1. The average amount of daily flight (only for airports with more than 1 flight/day) for Ukraine airports in the period from June 2016 to November 2019 [16]

This means that the resources of the local air traffic service units were used inefficiently. In addition to that, it is possible to see that a number of airports (e.g Vinnytsia, Kryvyi Rih and Chernivtsi) are affected by the variability of the traffic depending on the season – more flights during the summer season and less or none during winter (Figure 2).

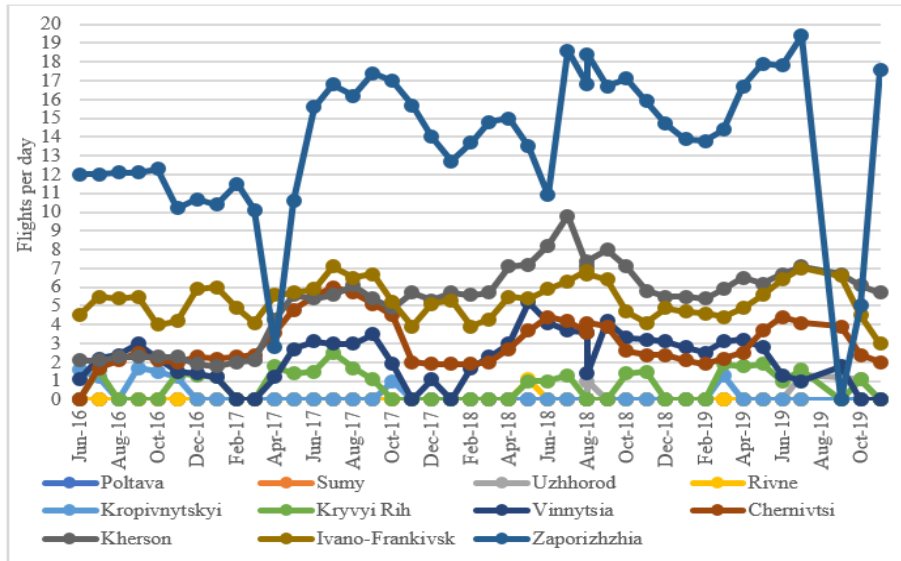


Fig. 2. Seasonal variability of daily flight (only for airports with more than 1 flight per day) for regional airports of Ukraine [16]

That is why it is not economically efficient to maintain the local aerodrome control tower to provide service to a small number of flights per day. One of the ways to optimize the use of resources at small regional airports is to implement a remote tower concept that could provide a more flexible approach to the provision of air traffic service, allocation of resources, through the effective using of RTCs for the performance of functions of the aerodrome control towers in areas with different air traffic intensity.

3 Remote tower concept and examples of its implementation

The main change introduced by the remote tower concept compared to the conventional air traffic service provided from a local tower is that the aerodrome control tower will be provided from a remote location and ATC and AFIS officers do not have to be physically present at the airport constantly.

As described in the previous section, one of the main operational requirements for the provision of air traffic service at an aerodrome is the ability of the ATC/AFIS officers to visually observe and survey the aerodrome and its portions that are under their responsibility.

That is why one of the main challenges for the remote tower concept is to comply with this requirement and provide ATC/AFIS officers with the necessary tools and means to reproduce the out of the window (OTW) view of the aerodrome. The OTW view is received through a number of cameras and can be combined with the data from sensors (e.g. surface movement radar, automatic dependent surveillance–broadcast (ADS-B), etc.) to improve the situational awareness of the ATC/AFIS officers [20].

Besides that, the ATC/AFIS officers should be equipped with a binocular functionality to replace a manual binocular which is currently in use at conventional aerodrome control towers. Similarly, to the manual binocular, the functionality should allow ATC/AFIS officers to visually survey certain items that could be of interest (e.g. landing gear of an aircraft, runway, etc.) [17].

The controller working position (CWP) is another significant part of the remote tower that allows ATC/AFIS officers to control air traffic from a remote location. To provide air traffic service all necessary systems and tools have to be available to ATC/AFIS officers that's why all systems (e.g. voice communication system, flight strip system, etc.) that are used in the conventional aerodrome control tower should be connected to the CWP in the remote tower.

Within the SESAR Programme a number of possible implementation options for the remote tower concept have been identified:

- Remotely provided ATS for a single airport;
- Remotely provided ATS for multiple airports;
- Remotely provided ATS for contingency cases.

In case of remotely provided ATS for a single airport, a remote tower module (RTM) has to be set up with CWP and OTW View of a single airport. This RTM might have more than one position (e.g. for another ATC officer or supervisor) depending on the complexity of the operating environment. For the remote ATS provision for multiple airports two configurations are possible:

- Sequential – RTM is connected to two or more airports but provide ATS to one airport at a time;
- Simultaneous – RTM is connected to two or more airports and provide ATS to multiple airports at the same time [18; 19].

To maximize the benefits from the implementation of remote tower concept a set of RTMs can be grouped into one centralized facility. This facility might provide ATS to multiple airports from the same location allowing to use resources more efficiently and reduce costs.

A set of RTMs might be grouped into a centralized facility that is known as an RTC. The RTC might house one or more RTMs providing ATS for one or several aerodromes from the same location allowing to optimise resources and costs (Figure 3) [20].

The remote tower concept has been already successfully implemented in a number of airports around the world. The first fully operational remote tower has been set up at Örnköldsvik airport (Sweden) in 2015. The service is provided from a city Sundsvall that is located around 150 km away from the airport. After some time, the service has been extended to cover also Sundsvall Timra airport, which means that both airports are served from a single RTC [20].

Norway has followed the example of Sweden and started a project to implement the remote tower concept and provide remote ATS from an RTC in Bodø. The aim of the project is to provide remote ATS service to 15 airports in 2020 [21].

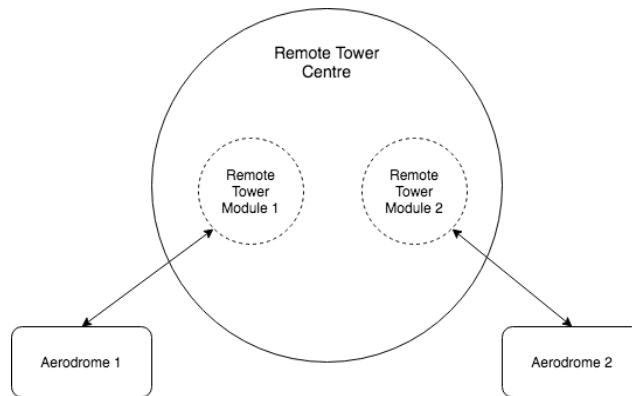


Fig. 3. Example of a set-up of an RTC

The German ANSP – Deutsche Flugsicherung (DFS) has launched a project to set-up an RTC in Leipzig to provide remote service to three international airports of Germany: Saarbrücken, Dresden and Erfurt. The target deadline for the project is the end of 2020 [22].

In addition to the abovementioned projects, a number of other projects have been launched in various countries in Europe and around the world: the United Kingdom, Hungary, the Netherlands, Australia, etc.

As presented above (statistics of Ukraine’s air traffic), Ukraine belongs to countries with developed airport infrastructure, but at the same time with an uneven distribution of flights at airports and seasonally. It is necessary to create a methodology for the selection of an optimal location of Remote Tower Centre (RTC) and to take investigations an application of a method of gradient descent to reduce the network latency or data transmission delay by minimizing the distance between the airport sites and RTCs.

4 Selection of an optimal location of a Remote Tower Centre

The provision of remote ATS requires a continuous exchange of information between the infrastructure at airport side and an RTM to ensure that the data received by ATCO/AFISO can be used to provide safe and orderly control of traffic. The typical equipment that is required to provide remote ATS include:

- High-resolution video cameras;
- Pan-tilt-zoom cameras;
- Video signal encoding equipment;
- High-resolution displays to provide the out-the-window view;
- Navigation and light systems;
- Surveillance and meteorological sensors, etc.

Due to the amount of video and audio data that has to be exchanged between an RTM or RTC and the local airport site in addition to other required data such as data from surveillance sensors, meteorological sensors, etc., the requirements for the network connection are very high [22].

However, one of the factors that have a high impact on network performance is latency in time. The network latency or data transmission delay can be defined as an expression of time needed for a data packet or message to travel from one end of the network to another. Ideally, the latency should be as close to zero as possible. The value of the latency depends on three main components [23]:

- Speed-of-light propagation delay that depends on the medium through which the light travels.
- Amount of time to transmit a unit of data that depends on the network bandwidth and the size of the data.
- Queuing-related delays.

This research focuses on the reduction of the propagation delay for the exchange of information to ensure that the latency of the network is as low as possible. The propagation delay can be determined as a ratio between distance over which the data has to travel and speed of the propagation. Since the speed is relatively constant and equals to speed of light in the given medium the only variable that can be changed is the distance. In the context of the remote tower concept, this is a distance between the airport site and RTM (or RTC).

Taking into account that the regional airports of Ukraine with small amounts of traffic are scattered throughout Ukraine, the most optimal way is to ensure the minimal distance between airport sites and RTCs would be grouping airports that are located nearby into segments and deploying RTCs per segment to serve airports within it. The proposed structure for the deployment of the remote tower concept in Ukraine is presented in Figure 4.

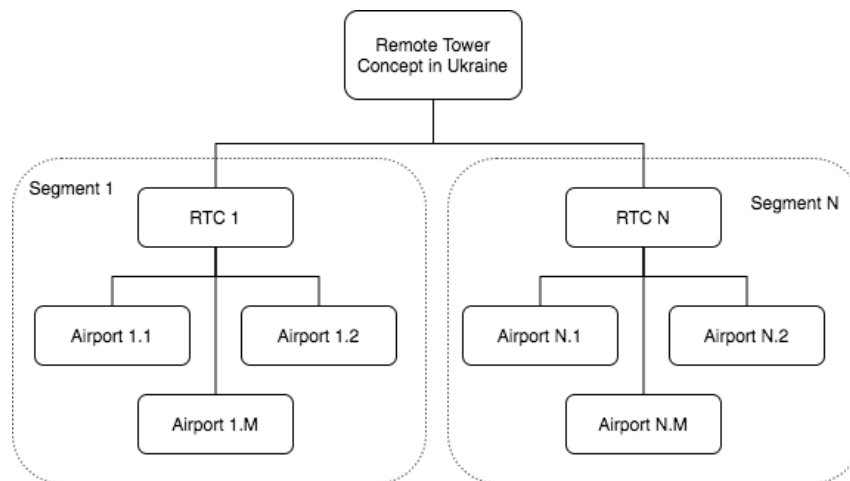


Fig. 4. The structure of the implementation of remote tower concept in Ukraine (N – number of segments; M – number of airports within a segment)

Based on this, a set of steps for the definition of an optimal location of Remote Tower Centre can be defined:

1. Grouping of airports into segments (for example, made in accordance with the map of Ukraine and the location of airports).
2. Calculation of coordinates of the Remote Tower Centre to minimize the distance between Remote Tower Centre and airports within the segment.
3. Refinement of coordinates based on other parameters (density of traffic, availability of resources, etc.).

In the mathematical terms the *Methodology (algorithm)* can be described as following:

STEP 1. For each airport, a list of the closest neighbours K is composed and frequency of appearance ω is calculated. For each airport distances among it and other airports are calculated, and based on them three (3) airports with the smaller distances are selected. Then in the list of the closest airports (which contains three closest airports for each airport) a frequency of appearance of an airport in the common list is calculated - ω .

If $\omega = \max \omega$ then for j airport $1 \leq \omega \leq \omega$. All airports with the same frequency i are added to the list S .

The lower limit for the frequency of appearance is calculated using the following equation:

$$\omega_a = \left[\frac{1}{n} \sum_{i=1}^{\omega^*} i \cdot Z_i \right] + 1 \quad (1)$$

where

Z – number of airports in the list S ;

$\left[\frac{1}{n} \sum_{i=1}^{\omega^*} i \cdot Z_i \right]$ – an integer part of a number;

n – number of airports.

STEP 2. Determine the initial set of coordinates for candidate locations of the Remote Tower Centre S_ω . After that, a set of airports is added in order of decrement of frequencies: $\omega \leq I \leq \omega$ taking into account that their number is limited by $n/2$.

The initial coordinates of the RTC are calculated as an average of airport coordinates within a segment:

$$x_{RTC} = \frac{1}{n} \sum_{i=1}^n x_i, \quad (2)$$

$$y_{RTC} = \frac{1}{n} \sum_{i=1}^n y_i; \quad (3)$$

where:

x, y – coordinates of airports within a segment;

n – number of airports in the segment.

These coordinates are used as a start point for the *Method of Gradient Descent* [24; 25].

STEP 3. To refine coordinates and optimize the coordinates of the RTC a method of gradient descent is used. During this step, it is necessary to minimize the sum of distances between an RTC and airports which are served by it. Therefore, for each segment it is necessary to minimize functional:

$$F(x_{RTC}, y_{RTC}) = \sum_{i=1}^n \sqrt{(x_{RTC}^j - x_i)^2 + (y_{RTC}^j - y_i)^2} \rightarrow \min \quad (4)$$

where $x_{RTC} \in E_j, y_{RTC} \in E_j$.

Minimization of the functional is made according to this algorithm:

3.1. Perform a search of initial approximation of RTC coordinates with (4). Determine the gradient of the functional $F(x_{RTC}, y_{RTC})$ in the initial approximation point:

$$B_1 = \sum_{i=1}^n \frac{x_{RTC}^j - x_i}{\sqrt{(x_{RTC}^j - x_i)^2 + (y_{RTC}^j - y_i)^2}} \quad (5)$$

$$B_2 = \sum_{i=1}^n \frac{y_{RTC}^j - y_i}{\sqrt{(x_{RTC}^j - x_i)^2 + (y_{RTC}^j - y_i)^2}} \quad (6)$$

Calculate $\sqrt{(B_1^2 + B_2^2)} < e$,
where $e \approx 0.01$ – accuracy.

If $\sqrt{(B_1^2 + B_2^2)}$ less than the accuracy than the necessary coordinates are found. Otherwise, move to the point of extreme.

$$x_{RTC}^{j+1} = x_{RTC}^j - hB_1 \quad (7)$$

$$y_{RTC}^{j+1} = y_{RTC}^j - hB_2 \quad (8)$$

where h – step towards gradient.

After recalculation of coordinates x_{RTC}^j, y_{RTC}^j by (7) and (8), the new values of functional $F(x_{RTC}, y_{RTC})$ are calculated and verified against $\sqrt{(B_1^2 + B_2^2)} < e$. This process is repeated until the value of the functional decreases. If on a step i the value of the functional increased and the condition $\sqrt{(B_1^2 + B_2^2)} < e$ is not satisfied, proceed to step 3.2.

3.2. During this step, a method of golden-section search. Compared to other methods, it requires the least amount of calculations and ensures the internal narrowing to the given accuracy. Step h is divided into uneven parts. These parts are selected in such a way that the ration of the length of the bigger segment (Z_1) to the length of the whole interval (Z) equals to the ration of the smaller segment (Z_2) to the bigger segment (“golden-section”):

$$\frac{Z_1}{Z} = \frac{Z_2}{Z_1}, Z_1 + Z_2 = Z \quad (9)$$

$$\frac{Z_2}{Z_1} = \left(\sqrt{5} - \frac{1}{2}\right) \approx 0.618 \quad (10)$$

On every step, the interval of uncertainty is decreased by $1/0.618$. For the further minimization, an interval of $[a; b]$ is considered, where $a = F(x_{RTC}^j, y_{RTC}^j)$ and $b = F(x_{RTC}^{j+1}, y_{RTC}^{j+1})$. To change the value of the step h let's set $a = h_0, b = h_1$. Then, according to the method of golden-section search, the new values of the steps are calculated using (11) and (12):

$$h_2 = h_0 + 0.382(h_1 - h_0); \quad (11)$$

$$h_3 = h_1 + 0.382(h_1 - h_0); \quad (12)$$

Calculate the values of $F(x_{RTC}^j, y_{RTC}^j)$ using the steps h_2 and h_3 and if $F(h_2) < F(h_3)$ then $h_3 = h_2$ (the right limit has changed), otherwise $h_2 = h_3$ (the left limit has changed). The process is continued until $h_1 - h_0$ does not become less than the given accuracy. After that go back to step 3.1.

The result will be a set of coordinates of optimal locations of RTCs from a point of view of minimization of distances between airports within one segment. However, this

is not the only factor that influences the decision of the selection of the location for the RTC, other such as the density of the traffic of airports within a segment, availability of resources at certain airports to house the RTC, availability of human resources, etc. should be also taken into account.

The defined methodology has been implemented as a computer program that takes a set of airports as an input and calculates a number of segments, performs allocation of airports to segments, calculates and refines coordinates of RTCs per each segment. The result of the execution of the computer program is shown in Figure 5. A set of airports is taken as an example and can be changed depending on the variation of the traffic. The received data and the analysis of abovementioned factors can be used to support the decision-making process of the selection of an optimal location for the RTC.

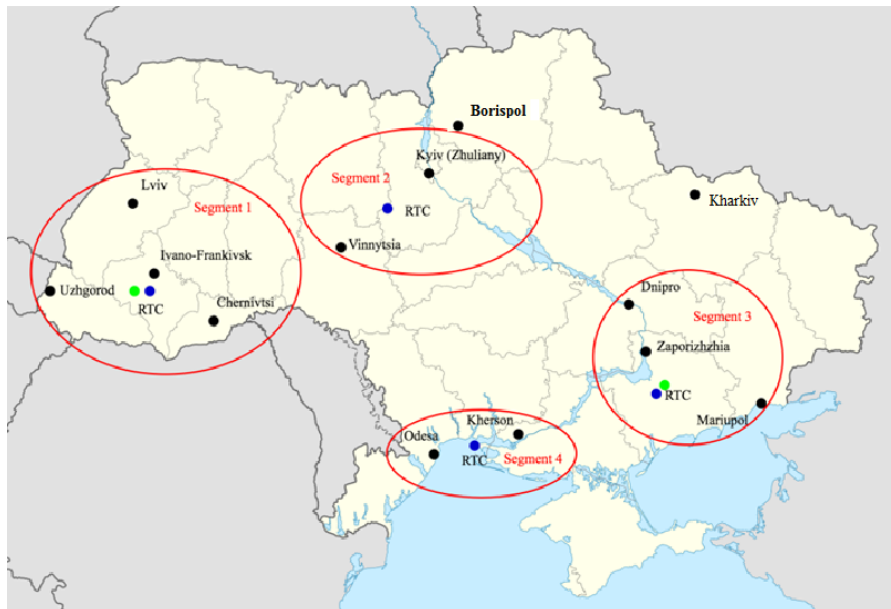


Fig. 5. The example of calculation of optimal locations (to minimize distance) of RTCs for Ukrainian airports (green dots – initial coordinates; blue dots – refined coordinates)

As seen from the received results, further analysis of them is required to select the most optimal locations for the RTCs. For example, the coordinates for the RTC of the Segment 4 point to a location in an open sea which makes it impossible to use it. That's why, as mentioned above, the minimization of distance to reduce the data transmission delay should be used in conjunction with other factors that could impact the location of the RTC, e.g. density of traffic, availability of resources, etc. Based on these other factors it might be considered more efficient to implement the RTC in Kherson or Odesa airport or another site even though it might have an impact on the network latency. Also, as seen, not all airports have been included in segments; it is meant that they will not be controlled remotely. For example, Boryspil has many flights and must be

controlled typically, Kharkiv is situated far away from others and distance will not allow providing real-time control from RTC because of delays.

To find the optimal location of the RTC, used the minimax/maximin decision criterion (Wald criterion) under conditions of uncertainty and compose a decision matrix (Table 1). If the Wald criterion is used, a guaranteed solution is obtained:

$$\text{Wald criterion (maximin): } A^* = \max_{A_i} \left\{ \min_{\lambda_j} u_{ij}(A_i, \lambda_j) \right\}.$$

The factors that influence on the alternative decision are defined as:

λ_1 – remoteness between RTCs;

λ_2 – location of the airports;

λ_3 – density of traffic;

λ_4 – availability of resources;

λ_5 – technical capabilities;

λ_6 – economic capabilities;

λ_7 – availability of RTCs to connections, etc.

Possible results in a matrix ($u_{ij}, i=1, \dots, n; j=1, \dots, 6$) are determined with the Expert Judgment Method by rating scales or based on statistical data.

Table 1. The matrix of decision making for choosing optimum location of the RTC.

Alternative decisions of location of the RTCs	Factors that influence decision making					
	λ_1	λ_2	λ_3	λ_4	λ_5	λ_6
A_1	u_{11}	u_{12}	u_{13}	u_{14}	u_{15}	u_{16}
...
A_i	u_{i1}	u_{i2}	u_{i3}	u_{i4}	u_{i5}	u_{i6}
...
A_n	u_{n1}	u_{n2}	u_{n3}	u_{n4}	u_{n5}	u_{n6}

Computer program "Classic Decision Criteria: Wald, Laplace, Hurwitz, Savage" for DM modeling was designed [26].

Therefore, it is necessary to perform an additional study to define and investigate other factors that could have an impact on the selection of the optimal location of the RTC and to enrich the current methodology with the defined factors. Once the methodology is defined completely it can be used also for other countries to select optimal locations for the RTCs.

5 Conclusion

To ensure consistent and coherent development of regional airports of Ukraine and consequently the development of air transportation network of Ukraine, there is a need to increase the level of traffic in the Ukrainian regional airports. One of the ways to achieve that is to decrease the costs of air transportation for airspace users and attract more flight to regional airports with lower costs.

The implementation of a remote tower concept allows to decrease the costs of air transportation through optimization of the use of resources and increase the cost efficiency of the provision of air traffic service at the airport. The remote tower concept has been successfully implemented or in the progress of implementation in multiple airports around the world (Sweden, Germany, Norway, etc.).

To ensure the availability of the necessary data for ATCO/AFISO to provide the safe and orderly remote ATS there is a need for continuous exchange of data between the infrastructure at airport site and RTM or RTC. Due to the amount of video and audio data that has to be exchanged in addition to other required data (surveillance, meteorological data, etc.) the requirements for the network performance are very high. One of the factors that have a high impact on network performance is latency.

This research focused on the reduction of one of the components of latency (the propagation delay) for the exchange of data to ensure that the latency of the network is as low as possible. The propagation delay can be determined as a ratio between distance over which the data has to travel and speed of the propagation. Since the speed is relatively constant and equals to speed of light in the given medium the only variable that can be changed is the distance. In the context of the remote tower concept, this is a distance between the airport site and RTM or RTC.

To minimize the distance between airports and RTCs and select optimal locations of RTCs the method of gradient descent has been used and adapted to fit the context of the regional airports of Ukraine.

The received method provides a set of coordinates of optimal locations of RTCs from a point of view of minimization of a distance between airports within one segment. However, this is not the only factor that influences the decision of the selection of the location for the RTC, other such as the density of the traffic of airports within a segment, availability of resources at certain airports to house the RTC, availability of human resources, etc. should be also considered. A separate follow-up study to define such factors and investigate their influence on the decision of the selection of the optimal location is needed.

Further research it is proposed to find the optimal location of the stations depending on the influence of several factors (the specific location of the RTCs depending on the location of the airports, the current intensity of air traffic, the workload of nearby airports, technical and economic capabilities, the availability of RTCs to connections with existing airports) using decision-making methods under risk and uncertainty [9; 12; 26; 27]. To evaluate the expected outcomes and the formation of the pay-off matrix, it is advisable to use artificial intelligence methods such as Big Data, Data Mining, Expert systems, Collaborative Decision Making, and others. Incorporating the promising approaches and technological advances will allow to evolve according to the increasing demands while offering safety and quality in the operation Air Traffic Management system [28].

In cases of large and complex big data, methods can be integrated into traditional and next-generation hybrid decision-making systems by processing unsupervised situation data in the deep landscape models, potentially at high data rates and in near real-time, producing a structured representation of input data with clusters that correspond to common situation types that is useful for minimizing latency in time when working RTCs and processing large amounts of information [27; 29].

The new methodology will include the process of integration deterministic, stochastic, and non-stochastic uncertainty models in complex situations. The Collaborative Decision-making models an uninterrupted process of presenting information between various interacting participants, as well as providing synchronization of decisions taken by participants and the exchange of information between them. It is important to ensure the possibility of making a joint, integrated solution with different operators at an acceptable level of efficiency. This is achieved by completeness, the accuracy of available information, and optimal solutions obtained [30].

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Choice method of analytical platform for smart cities

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Abstract. The smart cities development results in the expansion of the list of information technologies used for this purpose. These technologies are given below in the form of matrix and formal description. The proposed list of information technologies includes: Internet of Things, Fog Computing, Cloud Computing, Information Models, Intelligent Data Processing and Decision Support Systems, Mobile Technology, Geoinformation Technologies, GRID technology, Confidential Communication and Data Protection Technologies. While implementing the procedures for information technology support of the processes in smart cities, it is a common practice to use the models of analytical platforms which are on the open market. At present, their list is quite extensive. This fact creates uncertainty in the analytical platform selection. In order to select the analytical platform, the technique based on the hierarchy analysis method on the ground of procedure of pairwise comparisons of variants is proposed in this paper. The analysis was carried out among such alternative characteristics as computing resources and cloud infrastructure, availability and reliability, analytics, safety and security, cost, application programming interface, support. The obtained results show the highest efficiency of the method of the IBM Bigdata Analytics platform. It should be noted that the proposed method is to be implemented taking into account the probable need for the expansion of the set of analytical platforms characteristics and parameters.

Keywords: Multicriteria choice, Smart city, Data Processing, Analytical Hierarchic Processing, Information resources.

1 Introduction

Prototypes of modern city information systems must meet most closely principles formulated on the World Summit on the Information Society (WSIS) and ensure effective information technology for support of processes running in resource and so-

cio-communicational networks in the smart city with large population. For this purpose it is necessary to develop information technologies with implemented procedures of analytical processing of certain city data collections. Particularly such information technologies should give possibility to develop and utilize effective tools for analytical data processing implementation. A lot of such tools and means are based on the open analytical platforms providing their services both on commercial and free principles. System analysis of the processes, procedures and tools used for analytical processing of big data in smart cities is represented in paper [1]. Gupta [2] has analyzed data ecosystems and analytical data processing tools in smart cities that are integrated with different types of city systems and services. In paper [3], the authors note that the current investigation of the use of data and analytics means in cities is relatively inaccurate and fragmented and requires more holistic systematic approach. Picardal [4] presents the analysis of the information technologies that is used for city portal creation and for processes support in water supply networks in the Washington (USA). The above mentioned platform ensures flexible adding of functional components and system integration of new information technologies in it. Zschörnig in paper [5] presents the analysis of the original cloud information technology for IoT domains. The efficiency assessment of the offered prototype is carried out by the author. Arun in paper [6], investigating the architecture of IoT systems in smart cities, underlines the importance of the development and practice implementation of analytical data processing means as a separate structure layer. It makes it possible for the city to save the budget on acquiring of on-premises computing resources, with simultaneous decreasing of general financial expenses as payments only for hosting of consumed resources and services. There are a lot of (more than 60) analytic platforms represented on the market aimed for processing of urban data collections with wide list of available methods and tools. With this regard they are presented using various lists of different characteristics. Hence, the ambiguous situation arises in the procedures for selection the appropriate IT platform while developing IT component in smart cities with efficient data processing possibility. For such cases groups of experienced experts selected from available means the most "suitable" and the most "adopted" to the platform. As a consequence, the selection of completely functional, efficient, affordable and easy to use analytical platform is one of the urgent tasks of scientific researches and modern innovation information technology developments. Therefore, the objective of this paper is to facilitate the selection of information technology while designing the smart cities. The set goals result in the statement of the tasks concerning the formation of complete list of information technologies for smart cities and the development of a method for selecting the analytical platform for data processing in the smart city.

2 Information technologies of the smart city

The conclusion is based on the analysis of modern publications on the basis of the following information and communication technologies for smart cities formation [7]: Internet of Things (IoT) – IT_{IoT} , Fog Computing (FC) – IT_{FC} , Cloud Compu-

ting (CC) – IT_{CC} , Information Models (IM) – IT_{IM} , Intelligent Data Processing (IDP) and Decision Support Systems (DSS) – IT_{IDP} and IT_{DSS} , Mobile Technology (MT) – IT_{MT} , Geoinformation Technologies (GIS) – IT_{GIS} , GRID technology – IT_{GRID} , Confidential Communication and Data Protection Technologies – IT_{CCDP} . As the result based on the information technologies analysis and their functional coverage of main information processes the matrix is constructed. It is presented as a nested relation and shown in Fig. 1. Basic information technologies are given as an attributes, and types of information processes are given as the tuples.

Information process type	IT_{IoT}	IT_{MT}	IT_{GRID}	IT_{FC}	IT_{CC}	IT_{IM}	IT_{IDP}	IT_{GIS}	IT_{CCDP}
Data view		Mobile application for data presentation						Geographic context means of data presentation	
Data processing		Mobile calculations	GRID-calculations				OLAP Knowledge acquisition DSS Ontologies Big data analytics	Geographic data correlation	
Data collection		Foggy data preprocessing							
		Storage as a Service (STaaS)					DB		
		Data as a Service (DaaS)					Data warehouses		
		Big data storage					Data spaces		
Data transfer		Foggy means of data exchange							
	Communication means and IoT protocols of data exchange	Mobile networks						Geographic tagging of data transfer means	
			Resource GRID-networks						
Data load									
Data registration	IoT-devices and sensors	Mobile sensors	Smartphones					Geographic allocation of obtained data	
Data security									
									Block Chain IPFS

Fig. 1. Information technologies matrix of the smart city

Information technologies matrix is used for the determination of places, roles and connections between basic IT during smart city IT-platform (ITP) implementation. Normalized relation, given by information technologies matrix, are presented as follows:

$$ITP = \langle IT, D \rangle, \quad (1)$$

where $IT = \{IT_I\}$, $I = \{IoT, FC, CC, IM, IDP, DSS, MT, GIS, GRID, CCDP\}$ is a set of basic IT used for composing of ITP in modern smart cities;

$D = \{D_J\}$, $J = \{DS, DR, DL, DT, DC, DP, DV\}$ are the stages of data processing, particularly DR is data registration, DL is data load, DT is data transfer, DC is data collection, DP is data processing, DV is data view, DS is data security.

Detectors and sensors deployed on the bottom layer of the smart city information system (IS) (see Fig. 2) together with the means of data collection in socio-communicational environment are the main sources of heterogenous data sets generation.

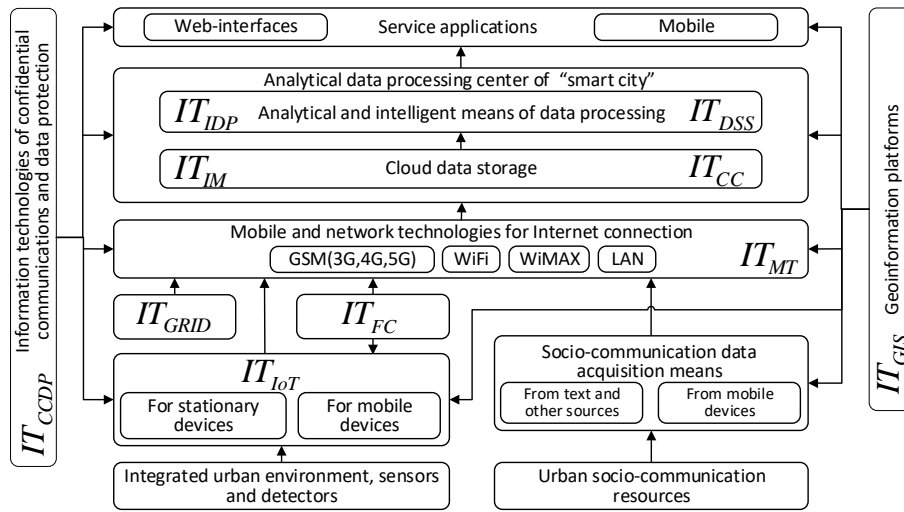


Fig. 2. Information technologies components that implement the smart city

Collected numerous big data sets of different types in information systems of the smart cities are processed typically by the center of analytical processing, which is as rule deployed on the base of cloud data storage [8]. Information sources associated with different components and subsystems of the smart cities make it possible to create big data sets that are not typically used rather effectively.

Modern infrastructure based on information technology enables to aggregate effectively generated data, to consolidate them and to process analytically in order to refine considerable the quality of base processes in urban systems.

3 Selection of the smart city analytical platform

It is proposed to select the analytical platform for smart city's needs with the application of the known expert method built on the procedure of pairwise comparisons of alternatives with the following steps:

Step 1. The three-layer hierarchy is built in order to get the possibility to apply the above mentioned method. There is the goal on the top level of the hierarchy and decision making is directed for this target. The second layer contains the set of criteria, with accounting of which the selection of the alternative analytical platform is conducted for analytical processing of urban data sets. Available alternatives compose the bottom level of the hierarchy. Decision making is conducted on the base of the composed vector of priorities and results in the selection of certain alternative among the available ones. The priority in our case is a real number that corresponds to each alternative. According to the heist priority, one alternative is selected and is treated as a taken decision. Corresponding three-layer hierarchic tree is shown in Fig. 3.

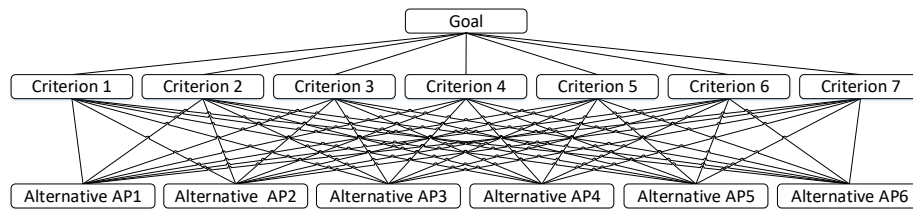


Fig. 3. General scheme of Analytical Hierarchic Processing method for the smart city analytical platform selection

Step 2. Composing the alternatives list. For instance, as the alternatives some popular ITP of analytical data processing are taken, particularly: 1) IBM Bigdata Analytics (AP_1) [9]; 2) HP Bigdata (AP_2) [10]; 3) Microsoft Bigdata (AP_3) [11]; 4) Oracle Bigdata Analytics (AP_4) [12]; 5) Google BigQuery (AP_5) [13]; 6) Cisco Bigdata (AP_6) [14].

Step 3. Assessment criteria listing on the base of the features analysis and possibilities of the selected platform use. The important factor for criteria listing, according to which the "best" ITP is selected, is the possibility of their adaptation to the needs of the smart city with large population. Particularly it also refers to Ternopil.

The set of criteria is formed as the result of system analysis of the selected APs functional possibilities. The pick of a certain analytic platform is made on the basis of these criteria. Seven characteristics of analyzed analytical platform are selected as the main criteria for alternatives weights calculation: computing resources and cloud infrastructure, availability and reliability, analytics, safety and security, cost, application programming interface (API), support.

Step 4. The selection of the scale for expert assessments. It is required to pick one of alternatives on the basis of the formed criteria set. The choice of the alternative is actually the calculation of elements priorities vector. Each element of this vector corresponds to a certain alternative. Thus, the decision making is based on the determination of the alternative with the greatest index. The scale of expert assessments is used for the implementation of Analytic Hierarchy Process (AHP): 1 is uniform importance (the importance of both objects is equal); 3 is weak importance (experienced experts judgments give the first object a slight advantage over the second); 5 is essential or significant importance (experienced experts judgments give the first object a big ad-

vantage over the second); 7 is very significant and obvious importance (first object superiority over second is very significant, explicit actually); 9 – absolute importance (first object superiority is more than convincing, actually indisputable); 2, 4, 6, 8 – intermediate values between adjacent scale values (compromised cases); inverse values – if one of the above values is obtained when comparing first object with second, then comparing the second object with the first is the inverse value.

The base of analytical platforms under analysis is that no one of them is oriented on the processing of urban data sets. The structure of the decision-making problem with AHP regarding to the selection of analytic platform is shown in Fig. 4.

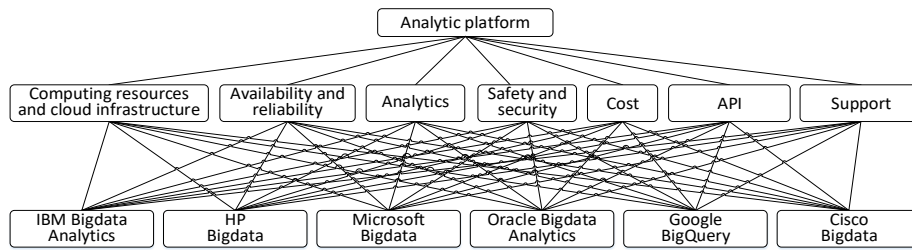


Fig. 4. The structure of the decision-making problem with AHP regarding to the selection of analytical platform for processes support in resource and socio-communication networks of smart cities

Step 5. The matrices of pairwise comparisons are built for each of the above listed criterion for AHP realization in order to select the analytical platform and corresponding numerical characteristics are calculated, particularly consistency index, the greatest eigenvalue and consistency ratio. Each of the above mentioned matrices contains expert assessments values regarding to the couples of the analyzed analytical platform. Additional arguments are given for each criterion concerning the particularities of information systems development and its application for the processes support in resource and socio-communication networks of the smart cities when matrices of pairwise comparisons for AHP are built. The "Computing resources" criterion defines the integral characteristics of calculative possibilities of ITPs for their dynamic allocation and release. The matrix of pairwise comparisons for analytical platform selection for "Computing resources and cloud infrastructure" criterion is shown in Table 1.

The results of weights assessments calculations for "Computing resources and cloud infrastructure" criterion are shown in Table 2. The best alternative for "Computing resources and cloud infrastructure" criterion is the analytical platform "IBM Bigdata Analytics" because it has the greatest calculated value of its weight 0.3524. For the matrix of pairwise comparisons, composed for "Computing resources and cloud infrastructure" criterion the following parameters are calculated:

— the assessment of the greatest eigenvalue:

$$\lambda_{\max} = \sum_{i=1}^n w_i s_i, \quad (2)$$

Table 1. The matrix of pairwise comparisons for alternatives selection for "Computing resources and cloud infrastructure" criterion

Alternatives	IBM Bigdata Analytics	HP Bigdata	Microsoft Bigdata	Oracle Bigdata Analytics	Google BigQuery	Cisco Bigdata
IBM Bigdata Analytics	1	2	3	5	2	7
HP Bigdata	0.5	1	3	5	3	5
Microsoft Bigdata	0.33	0.33	1	3	1	3
Oracle Bigdata Analytics	0.2	0.2	0.33	1	1	1
Google BigQuery	0.5	0.33	1	1	1	3
Cisco Bigdata	0.14	0.2	0.33	1	0.33	1
Total	2.68	4.07	8.67	16	8.33	20

Table 2. Alternatives weights for "Computing resources and cloud infrastructure" criterion

Alternatives	IBM Bigdata Analytics	HP Bigdata	Microsoft Bigdata	Oracle Bigdata Analytics	Google Big- Query	Cisco Big- ata	Total	Alternative's weight
IBM Bigdata Analytics	0.3737	0.4918	0.3462	0.3125	0.24	0.35	2.114	0.3524
HP Bigdata	0.1868	0.2459	0.3462	0.3125	0.36	0.25	1.7014	0.2836
Microsoft Bigdata	0.1246	0.082	0.1154	0.1875	0.12	0.15	0.7794	0.1299
Oracle Bigdata Analytics	0.0747	0.0492	0.0385	0.0625	0.12	0.05	0.3949	0.0658
Google BigQuery	0.1868	0.082	0.1154	0.0625	0.12	0.15	0.7167	0.1194
Cisco Bigdata	0.0534	0.0492	0.0385	0.0625	0.04	0.05	0.2935	0.0489
Total	1	1	1	1	1	1	6	1

— consistency index:

$$C_I = \frac{\lambda_{\max} - n}{n - 1}; \quad (3)$$

— consistency ratio:

$$C_R = \frac{C_I}{R_I}. \quad (4)$$

The same value of random consistency index is used $R_I = 1,25$ for the following calculations of alternatives weights when $n = 6$.

The above mentioned calculated parameters for the matrix of pairwise comparisons for "Computing resources and cloud infrastructure " criterion are as follows:

– assessment of the greatest eigenvalue:

$$\lambda_{\max} = 0,3524 \cdot 2,68 + 0,2836 \cdot 4,07 + 0,1299 \cdot 8,67 + 0,0658 \cdot 16 + 0,1194 \cdot 8,33 + 0,0489 \cdot 20 = 6,2487; \quad (5)$$

– consistency index:

$$C_I = \frac{\lambda_{\max} - n}{n - 1} = \frac{6,2487 - 6}{6 - 1} = 0,0497; \quad (6)$$

– consistency ratio:

$$C_R = \frac{C_I}{R_I} = \frac{0,0497}{1,25} = 0,0398. \quad (7)$$

It is obvious that $C_R = 3,98\% \leq 10\%$, so the matrix of pairwise comparisons for "Computing resources and cloud infrastructure" criterion is consistent.

Matrices of pairwise comparisons for the selection of ITPs by "Availability and reliability", "Analytics", "Safety and security", "Cost", "API" and "Support" criteria and calculated alternatives weights for the listed criteria are calculated in same way. Similar to "Computing resources and cloud infrastructure " criterion, the eigenvalues λ_{\max} , consistency indices C_I and ratio indices C_R are calculated for all of these criteria and shown in Table 3.

Table 3. Parameters of matrices of pairwise comparisons

Criterion	λ_{\max}	C_I	C_R
Computing resources and cloud infrastructure	6,249	0,05	0,04
Availability and reliability	6,243	0,049	0,039
Analytics	6,493	0,099	0,079
Safety and security	6,265	0,053	0,042
Cost	6,495	0,099	0,079
API	6,377	0,075	0,06
Support	6,432	0,086	0,069

The equation $C_R \leq 10\%$ is true for all criteria ensuring the consistency for each matrix of pairwise comparisons.

Step 6. Alternative weights assessment. The assessment of the importance grade with respect to each criterion is performed for alternatives weights estimation (see Table

Step 7. Results of weighting. Weighted results of the analytical platform selection are given in Table 6.

Table 6. Weighted results with respect to criteria for analytical ITP selection

Platform	Criteria	Computing resources and cloud infrastructure	Availability and reliability	Analyt-ics	Safety and security	Cost	API	Support
IBM Bigdata Analytics		0.1208	0.1039	0.0254	0.0271	0.0446	0.0194	0.0225
HP Bigdata		0.0972	0.0748	0.0056	0.0263	0.0174	0.0084	0.0395
Microsoft Bigdata		0.0445	0.0282	0.0036	0.0193	0.0049	0.0035	0.003
Oracle Bigdata Analytics		0.0226	0.0129	0.0053	0.0082	0.0106	0.004	0.0111
Google BigQuery		0.0409	0.0344	0.0082	0.098	0.0146	0.004	0.0052
Cisco Bigdata		0.0168	0.0129	0.0161	0.0043	0.0065	0.0018	0.0101
Consistency index		0.0171	0.013	0.0063	0.005	0.098	0.0031	0.0079
Total		0.3427	0.2671	0.0641	0.095	0.0985	0.0411	0.0914

The best alternatives of ITPs with respect to the given criteria and corresponding weights are shown in Table 7.

Table 7. The best alternatives and corresponding weights of analytical ITPs choosing

Criterion	The best alternative	Weight
Computing resources and cloud infrastructure	IBM Bigdata Analytics	0.3524
Availability and reliability	IBM Bigdata Analytics	0,3389
Analytics	IBM Bigdata Analytics	0,4026
Safety and security	IBM Bigdata Analytics	0,3961
Cost	IBM Bigdata Analytics	0,2853
API	IBM Bigdata Analytics	0,4528
Support	HP Bigdata	0,4326

4 Results

In order to assess the reliability of the obtained solution while selecting the alternative, we use the consistency index, containing information about the violation of numerical (cardinal) and transitive consistency of matrices. The limits of application of the hierarchies analysis method are defined if the consistency index is less than 0.1. In the carried out investigation, the calculated consistency index is

0.033, which indicates the high level of the obtained solution reliability. The results of weights calculations are presented in Table 8 and Fig. 5.

Table 8. Alternatives and their weights

Alternative	Weights
IBM Bigdata Analytics	0.0462
HP Bigdata	0.0386
Microsoft Bigdata	0.018
Oracle Bigdata Analytics	0.0122
Google BigQuery	0.0177
Cisco Bigdata	0.0101

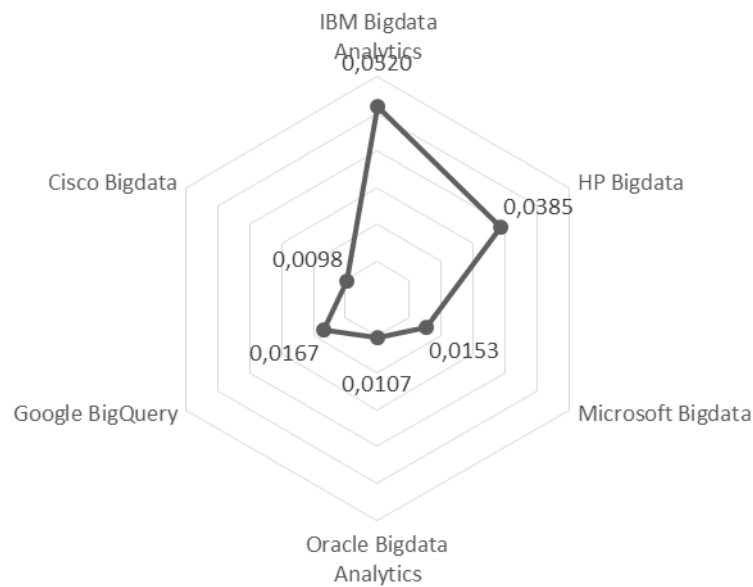


Fig. 5. Diagram of alternative analytical platforms weights

The recommendation for the selection of "IBM Bigdata Analytics" analytical platform are given on the basis of the above mentioned calculations, because investigated alternative has the greatest weight and fits for analytical processing of urban data sets.

5 CONCLUSION

The list of information technologies for the smart cities, which includes: Internet of Things, Fog Computing, Cloud Computing, Information Models, Intelligent Data Processing and Decision Support Systems, Mobile Technology, Geoinformation

Technologies, GRID technology, Confidential Communication and Data Protection Technologies is formed in this paper. It is offered to implement the selection of the best variant with the application of the method formed on the basis of hierarchies analysis. It is based on the procedure of pairwise comparisons of variants.

The method offered by the authors is applied for solution of the problem of efficient selection of the analytical platform for smart cities in the context of efficient creation for development information systems in Ternopil, that are carried out by the team of researchers from Ternopil National Technical University and National University "Lviv Polytechnic".

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Method of Forming a Logical Conclusion about Legal Responsibility in the Cybersecurity Domain

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Abstract. Cyber attacks on critical infrastructure's objects can have dire consequences, as our entire lives depend on the working capacity of such systems. In Ukraine, cybercrime provides for criminal and civil liability under the Criminal and Civil Codes of Ukraine, and under the Law of Ukraine “On the Fundamental Principles of Cyber Security in Ukraine”. A successfully implemented decision-making support system that can provide a conclusion of legal responsibility in the cybersecurity domain, namely, propose sanctions recommended in the case of an offence or multiple offences, can significantly improve the productivity of the Ukrainian cyber police. This paper explores the legal and organizational principles of cybersecurity in today's information society, and first time develops the method and production rules of forming a logical conclusion about legal responsibility in the cybersecurity domain, that are used to form the conclusion about legal responsibility, namely for the selection of a sanction or set of sanctions recommended in the event of a particular offence or multiple cyber-security offences.

Keywords: cybersecurity, cyberattacks, cybersecurity offences, sanctions, legal responsibility in the cybersecurity domain, logical conclusion about legal responsibility in the cybersecurity domain.

1 Introduction

The modern development of an information society is directly linked to the need to collect, process and transmit vast amounts of information. The main criteria of the information society are the amount and quality of available information, the efficiency of its transmission and processing, the accessibility of information for everyone. So, information management is becoming a business-critical function. So the main strategic goal of the development of the information society in Ukraine is providing the security and protection of information. The issue of information security becomes more acute [1].

Cyber-attacks on critical infrastructure's systems pose real threats to the safety of the human community, lead to human casualties, environmental disasters, and significant financial losses.

Today, on a monthly basis, Ukraine undergoes cyber attacks 3000-3500 times. In the last 12 months, every second industrial company in the world has experienced one to five cyber incidents. The loss of the world economy as a result of cyber-attacks is 445 billion USD. Losses to Ukrainian businesses caused by the cyber-attacks amount to 25 million USD [2]. Every 4 seconds an unknown malware is downloaded – Fig. 1 [3].



Fig. 1. An Average Day at an Enterprise Organization [3].

So the actual problem with using computer systems is the robust protection of information against cyber threats.

Therefore, most countries in the world carry out comprehensive measures to ensure national cybersecurity. These measures relate, first and foremost, to the development and improvement of regulations, as well as to the establishment of departmental and state structures that regulate and be responsible for ensuring the security in the cyberspace [4].

In 2001, the European Commission presented the first document entitled "Network and Information Security: A Proposal for A European Policy Approach" [5]. The European Union Agency for Network and Information Security (ENISA) was established on 10 March 2004 [6]. In May 2007, the European Commission presented the document "Towards a general policy on the fight against cybercrime" [7]. European Commission policy on cybercrime opposition encourages the signing by the EU Member States and other countries of the Convention on Cybercrime. The message of the European Commission "Protecting Europe from large scale cyber-attacks and disruptions: enhancing preparedness, security and resilience" [8] was published in March 2009. On February 7, 2013, the European Commission approved the Cybersecurity Strategy of the European Union: An Open, Safe and Secure Cyberspace [9]. The European CyberCrime Center was

established in Europol (European Police Office), which started its operations in January 2013 in The Hague (Netherlands). On 6 July 2016, Directive (EU) 2016/1148 of the European Parliament and of the Council concerning measures for a high common level of security of network and information systems across the Union [10] was adopted. On 13 September 2017, the European Commission presented the document "Resilience, Deterrence and Defense: Building strong cybersecurity for the EU" [11]. Every year, the European Cybercrime Center publishes an Internet Organised Crime Threat Assessment (IOCTA) [12]. On December 14, 2016, Ukraine signed an Agreement between Ukraine and the European Police Office on operational and strategic cooperation [13].

In Ukraine, cybercrime provides for criminal and civil liability under the Criminal Code [14] and the Civil Code [15] of Ukraine (Articles 277, 278, 280), as well as under the Law of Ukraine "On the Fundamental Principles of Cyber Security in Ukraine" [16].

2 Problem Statement

A successfully implemented decision-making support system that can provide a conclusion about legal responsibility in the cybersecurity domain, namely, propose sanctions recommended in the case of an offence or multiple offences, can significantly improve the productivity of the Ukrainian cyber police. For developing this decision support system, a method and production rules of forming a logical conclusion about legal responsibility in the cybersecurity domain should be developed, which is *the purpose of this research*.

Such a decision support system, like any decision support system (DSS), can be represented as a formal system:

$$C = \langle A, PR, M \rangle, \quad (1)$$

where C is the set of alternatives (conclusions) that are generated by DSS; A is the set of the basic elements (set of actions (offences), which entail certain sanctions under the current legislation of Ukraine); PR is the set of rules by which alternatives are generated for objects with A ; M are methods used in data processing.

The DSS inputs (set A) are actions (offences), which entail certain sanctions under the current legislation of Ukraine. The outputs of the DSS (set C) are the results of the data analysis, on the basis of which the decisions are generated, as well as the decisions (conclusions about the sanction(s), which recommended in the case of committing an action (offence) or a few actions (offences)). Then the relationship between the input and output parameters is a mathematical description of DSS:

$$C = M(A), \quad (2)$$

where M is a method that allows to parameters of A to match an alternative of C using the production rules of PR .

In order to achieve the purpose of this research, *the following tasks* must be solved:

- developing the production rules (set PR) and method (M) of forming a logical conclusion about legal regulations in the cybersecurity domain;

- design of decision support system for forming a logical conclusion about legal regulations in the cybersecurity domain, for the selection of sanctions, which are recommended in the case of the cybersecurity offence or multiple offences.

3 Production Rules and Method of Forming a Logical Conclusion about Legal Responsibility in the Cybersecurity Domain

First of all, we will develop production rules of forming a logical conclusion about legal responsibility in the cybersecurity domain (set $PR = \{pr1, \dots, pr13\}$) based on the norms of the Criminal [14] and the Civil [15] codes of Ukraine (Articles 277, 278, 280), and the norms of the Law of Ukraine “On the Fundamental Principles of Cyber Security in Ukraine” [16].

For this purpose, we will form a set of actions (offences), which entail certain sanctions under the current legislation of Ukraine: $A = \{a1, \dots, a10\}$, where $a1$ – unauthorized interference with the operation of computers, automated systems, computer networks or telecommunication networks, that have led to leakage, loss, tampering, blocking of information, distortion of the information processing process or disruption of established routing order; $a2$ – re-committing; $a3$ – preliminary conspiracy of a group of persons; $a4$ – causing significant damage (damage that exceeds the tax-free minimum income of citizens 100 times or more); $a5$ – creation for the purpose of use, distribution or sale, as well as distribution or sale of malicious software or hardware, which intended for unauthorized interference with the operation of computers, automated systems, computer networks or telecommunication networks; $a6$ – unauthorized sale or distribution of restricted information, which stored in computers, automated systems, computer networks or on special media of such information; $a7$ – unauthorized modification, destruction or blocking of information, that is processed in computers, automated systems or computer networks or stored on special media of such information; $a8$ – unauthorized interception or copying of information, that is processed in computers, automated systems, computer networks or stored on special media of such information, which led to information leakage; $a9$ – violation of the rules of operation of computers, automated systems, computer networks, telecommunication networks or of the order or rules of protection of the processed information, which caused significant damage; $a10$ – intentional mass distribution of messages, which was made without the prior consent of the addressees, that has led to the disruption or termination of the operation of computers, automated systems, computer networks or telecommunication networks.

Given the set of actions (offences) A , the production rules of forming a logical conclusion about legal regulations in the cybersecurity domain are the set $\{pr1, \dots, pr13\}$:

$pr1$ = “if the person has committed action $a1$, then and only then such person shall be punished by a fine of six hundred to one thousand tax-free minimum incomes, or by restriction of liberty for a term of two to five years, or imprisonment for up to three years, with deprivation of the right to occupy certain positions or engage in certain activities for a term up to two years”;

$pr2$ = “if the person has committed action $a1$ and action $a2$ and/or action $a3$ and/or action $a4$, then and only then such person shall be punished by imprisonment for a

term of three to six years, with deprivation of the right to occupy certain positions or engage in certain activities for up to three years”;

pr3="if the person has committed action *a5*, then and only then such person shall be punished by a fine of five hundred to one thousand tax-free minimum incomes, or by correctional labour for a term up to two years, or imprisonment for the same term”;

pr4="if the person has committed action *a5* and action *a2* and/or action *a3* and/or action *a4*, then and only then such person shall be punished by imprisonment for a term up to five years”;

pr5="if the person has committed the action *a6*, then such person shall be punished by a fine of five hundred to one thousand tax-free minimum incomes, or imprisonment for a term up to two years”;

pr6="if the person has committed action *a6* and action *a2* and/or action *a3* and/or action *a4*, then and only then such person shall be punished by imprisonment for a term of two to five years”;

pr7="if the person has committed action *a7*, then and only then such person shall be punished by a fine of six hundred to one thousand tax-free minimum incomes or corrective labour for a term up to two years”;

pr8="if the person has committed action *a7* and action *a2* and/or action *a3* and/or action *a4*, then and only then such person shall be punished by imprisonment for a term of three to six years, with deprivation of the right to occupy certain positions or engage in certain activities for up to three years”;

pr9="if the person has committed the action *a8*, then and only then such person shall be punished by imprisonment for a term up to three years, with deprivation of the right to occupy certain positions or engage in certain activities for the same term”;

pr10=" if the person has committed action *a8* and action *a2* and/or action *a3* and/or action *a4*, then and only then such person shall be punished by imprisonment for a term of three to six years, with deprivation of the right to occupy certain positions or engage in certain activities for up to three years”;

pr11="if the person has committed action *a9*, then and only then such person shall be punished by a fine of five hundred to one thousand tax-free minimum incomes, or a restriction of liberty for a term up to three years, with deprivation of the right to occupy certain positions or engage in certain activities for the same term”;

pr12="if the person has committed action *a10*, then and only then such person shall be punished by a fine of five hundred to one thousand tax-free minimum incomes, or by restriction of liberty for a term up to three years”;

pr13="if the person has committed action *a10* and action *a2* and/or action *a3* and/or action *a4*, then and only then such person shall be punished by restriction of liberty for a term up to five years, with deprivation of the right to occupy certain positions or engage in certain activities for up to three years”.

On the basis of the developed production rules, we will develop the *method of forming a logical conclusion about legal regulations in the cybersecurity domain*:

1. the set of actions (offences) $A_{real} = \{a1_{real} \dots, an_{real}\}$, which are committed by the offender, is formed, where n is the number of offences committed by a concrete offender;

2. by the method of searching in the breadth in the forward direction, in the set of production rules $\{pr1, \dots, pr13\}$, a rule(s) is(are) searched for each of the elements of the set $\{a1_{real}, \dots, an_{real}\}$;
3. according to the selected rules, the conclusion is drawn about the sanction(s), which recommended in the case of committing an action (offence) or a few actions (offences); if the rule is not found, then there is no sanction(s) accordance with the modern legislation of Ukraine.

The scheme of the developed method of forming a logical conclusion about legal regulations in the cybersecurity domain is represented on Fig. 2.

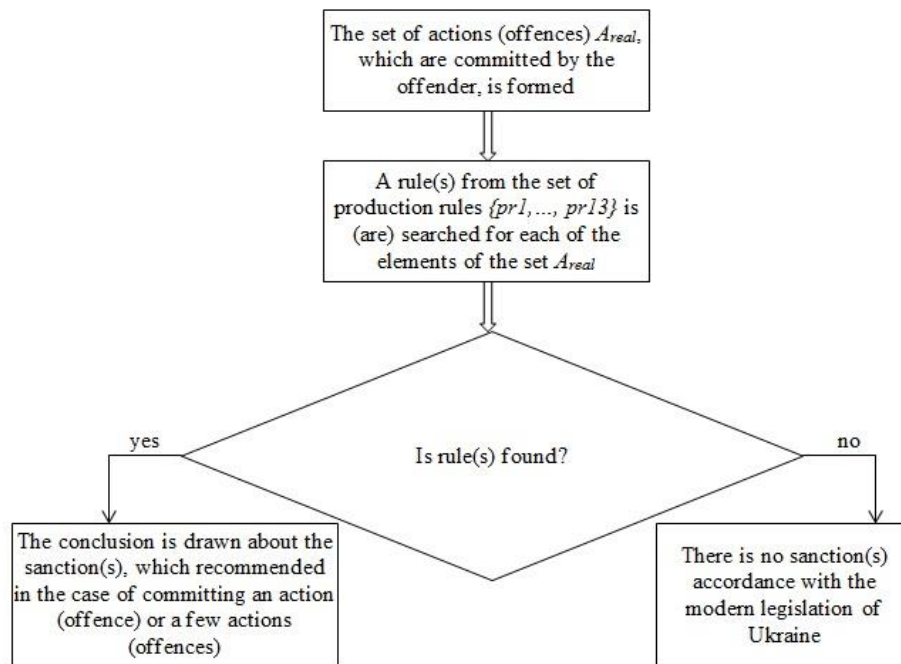


Fig. 2. The scheme of the developed method of forming a logical conclusion about legal regulations in the cybersecurity domain.

4 Results & Discussions

Examples of forming a logical conclusion about legal regulations in the cybersecurity domain. Person1 has created and distributed a new computer virus $V1$, which is designed for unauthorized interference with the operation of the computer network of Enterprise1. Then for this case the set $A_{real} = \{\text{"creation for the purpose of use, distribution or sale, as well as distribution or sale of malicious software or hardware, which intended for unauthorized interference with the operation of computers, automated systems, computer networks or telecommunication networks"}\}$. In the set of production rules, the search of rule for the action (offence) from the set A_{real} is

executed – this is *pr3*. According to this rule, the conclusion about the sanction, which recommended in the case of committing this action (offence), has the form: “*Person1 shall be punished by a fine of five hundred to one thousand tax-free minimum incomes, or by correctional labour for a term up to two years, or imprisonment for the same term*”.

Person2 performed unauthorized modification of information, that is processed in automated system of Enterprise2. Then for this case the set $A_{real} = \{\text{“unauthorized modification, destruction or blocking of information, that is processed in computers, automated systems or computer networks or stored on special media of such information”}\}$. In the set of production rules, the search of rule for the action (offence) from the set A_{real} is executed – this is *pr7*. According to this rule, the conclusion about the sanction, which recommended in the case of committing this action (offence), has the form: “*Person2 shall be punished by a fine of six hundred to one thousand tax-free minimum incomes or corrective labour for a term up to two years*”.

Discussions. The authors analyzed the materials of 20 cases initiated against persons who committed cybersecurity offences, in which the court decided to return for revision to the cyber police due to incorrectly formulated requests for sanctions. Analysis of the data from these cases using the developed rules method of forming a logical conclusion about legal regulations in the cybersecurity domain showed that if the developed method was used before the case was sent to court, all correct decisions on the necessary sanction would be made. Therefore, the use of developed rules and methods can increase the level of correctness of decisions on the required sanction to 100%. Thus, the decision support system for the selection of sanctions, which are recommended in the case of cybersecurity offences or multiple offences, will provide rapid and automatic verification of all cases against perpetrators of cybersecurity offences, in terms of the choice of sanctions for such persons.

5 Conclusions

At present, in the age of the information society, cyber weapons in terms of efficiency and impact can be equated with weapons of mass destruction. The faster humanity develops information technologies, the greater is the need to protect them, to ensure their cybersecurity. Today, no state can say with certainty that its networks are fully secure and able to withstand multi-vector cyberattacks, so cybersecurity has become a priority in many countries. At first glance, it may seem that cyberattacks cannot do much harm or take lives, but attacks on critical infrastructure's objects can have dire consequences, since our entire lives depend on the working capacity of such systems.

A successfully implemented decision-making support system that can provide a conclusion of legal responsibility in the cybersecurity domain, namely, propose sanctions recommended in the case of an offence or multiple offences, can significantly improve the productivity of the Ukrainian cyber police.

This paper first time develops the method and production rules of forming a logical conclusion about legal responsibility in the cybersecurity domain, that are used to form the conclusion about legal responsibility, namely for the selection of a sanction(s) recommended in the event of a particular offence or multiple cyber-security offences.

The perspective directions of future authors' work are the designing, developing and implementing the decision support system for the selection of sanctions, which are recommended in the case of the cybersecurity offence or multiple offences. The basis of such the system will be developed in this paper production rules and method of forming a logical conclusion about legal responsibility in the cybersecurity domain.

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Experimental FMECA-based Assessing of the Critical Information Infrastructure Importance in Aviation

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Abstract. Up-to-date information and communication technologies (ICT) implementation in various industries, on the one hand, increases the efficiency of different business processes and, on the other hand, generates new threats and vulnerabilities in ICT. Critical infrastructures (CI) need principal new effective methods and means for cybersecurity ensuring. In the situation with limited resources, CI objects defining and ranking is an important task. To rank objectively, CI objects should be assessed using some criteria. Previously, authors have proposed a FMECA-based method to assess importance level for state critical information infrastructure, which allows ranking and evaluating the importance of CI objects using both quantitative and qualitative parameters. This paper presents a complex experimental study of the proposed method using the aviation industry as an example. An experimental technique was introduced and using it, the adequacy of method response to changing input data was checked. It confirmed the possibility of importance level assessment of critical aviation information systems related to various categories: information systems for air navigation services; on-board information systems for aircraft; information systems for airlines and airports.

Keywords: critical information infrastructure, importance level assessment, critical aviation information systems, experimental study, cybersecurity, aviation.

1 Introduction

Information and communication technologies (ICT) rapid development has led to significant and sometimes revolutionary changes in all spheres of people's lives in most states of the world. This has significantly increased the vulnerability of various

networks, systems and ICT objects and has made it difficult to ensure their protection and security. All these factors have caused the world's leading states to pay significant attention to the protection of critical facilities, systems and resources, as well as to the identifying critical infrastructures (CI) [1-2], assessing their criticality level and impact of possible functional interruptions (failures). However, today there is no universal method that could be used to assess the criticality level of CI in different industries using both quantitative and qualitative parameters.

2 Related papers analysis

Increasing concentration of means and resources for protecting CI of different types necessitated the ranking of CI objects, the selection of the most important ones and the emergence of the CI concept [3-4]. ICT is important part of CI called critical information infrastructure (CII). In order to protect the most important CII objects, it is necessary to first identify these objects by certain criteria [5] and then determine the criticality (assess the importance) of the identified objects [6]. Particular attention needs to be given to aviation, where, in accordance with the guidance documents [7], so-called critical aviation information systems (CAIS) need to be identified and protected against various cyberthreats. In works [8-10] the FMECA-based (Failure Mode, Effects and Criticality Analysis) approach for assessing CII objects in different industries of CI was presented and studied.

3 Problem statement

In the study [1] authors have proposed a FMECA-based method of assessing the importance level of CII objects in aviation, which makes it possible to evaluate the importance level and to rank the CAIS [10]. This method uses the introduction of a basic set of systems and corresponding sets of subsystems, components, functions, violations of continuity of work (interruption of work, loss of functionality), their features and consequences, as well as the construction of a three-dimensional criticality matrix.

The main results of the implementation of the proposed method are presented in the form of a report, which summarizes such information as: a list of system components, their functions, types of interruptions for each component of the system; information on the causes and consequences of interruptions for each component of the system; calculations of criticality rankings, ranking results are a list of the most significant (critical) interruptions of work, which are displayed in a formalized and convenient for experts form. Other output data was obtained at different stages of the method implementation: criticality matrix, which according to the collected preliminary data graphically reflects the criticality of the system components (stage 7); Pareto diagram which shows the level of criticality inside the system and makes it possible to compare several different systems (stage 9); Ishikawa's cause and effect diagram that allows to identify priority areas for developing appropriate corrective measures (stage 10).

The previously proposed method by authors in [1] is implemented in the following stages: 1) identification of system components and setting the level of detail; 2) defining the functions of each detected system component; 3) determining the list of possible interruptions of each system component; 4) determining the consequences of each possible work interruption; 5) identification of interruption detection signs; 6) identification of methods for detecting work interruptions; 7) construction of a three-dimensional criticality matrix; 8) calculation of the criticality rank of probable interruptions; 9) selection of the list of the most significant (critical) work interruptions; 10) forming a list of corrective measures; 11) report generation.

The main task of this work is experimental study of method for importance level assessing of the CII objects in aviation (CAIS). This method was proposed by authors before [1] and it is based on FMECA technique with proposed improvements for effective quantitative and qualitative assessment.

4 The main part of the study

A. Experimental technique description

The first step of experimental research is the creation of *an experimental program*, which contains the following components:

1. The purpose and objectives of the experiment. The purpose of the experiment is to investigate the adequacy of the developed method.

Objectives:

1.1. Investigate the proposed method of assessing the importance of CII objects in aviation (by modeling its operation using developed software).

1.2. Check the adequacy of the developed method's response to changing the input data.

1.3. Check the adequacy of the developed severity weight coefficients of the interruption consequences for the developed method.

2. Selection of input and output parameters:

2.1. Input parameters for solving problem 1.1. are: structural and functional diagrams of the analyzed system and its components; information on the functioning of each process or system component; a detailed description of all the parameters that may affect the functioning of the system; information about the results of work interruption; chronological work interruption data, including available work interruption intensity data. Output parameters: a report listing the types of interruptions for each system component; information on the causes and consequences of interruptions for each system component; criticality matrix; Pareto diagram; Ishikawa's cause and effect diagram; a list of corrective measures to reduce the criticality of the most significant work interruptions.

2.2. Input parameters for solving problem 1.2. are: a list of all types of system component interruptions and their estimated criticality level. Output parameters: summarized results of the study of each system interruptions.

2.3. Input parameters for solving problem 1.3 are: metrics tables B_{1i}, B_{2i}, B_{3i} , and calculated values for the weighting coefficients of work interruption consequences.

Output parameters: results of the study of the developed weight coefficients of work interruption consequences.

3. The order of actions:

3.1. Determining the set of system **C** components with the help of set of classes of systems **S**, set of systems \overline{S}_i , set of subsystems \overline{S}_{ij} , and setting of level of detail Det_{\min} (using accordingly (6), (1), (2) and (4) in [1]).

3.2. Determining the set of functions **F**, and the set of work interruptions **D** (using accordingly (7) and (8) in [1]).

3.3. Determining the set of consequences **E**, signs of detection **O**, ways of detecting work interruptions **W** (using accordingly (9), (10) and (12) in [1]) and building a three-dimensional criticality matrix.

3.4. Calculating of the set of criticality ranks of possible interruptions **R**, with the help of sets $\overline{B}_1, \overline{B}_2, \overline{B}_3$, selecting the list of most significant work interruptions *criticality* (D_i), (using accordingly (13) – (18) in [1]), of set **VK** (see stage 8 of experimental research) and construction of the Pareto diagram.

3.5. Constructing a cause-and-effect diagram of Ishikawa, determining the set of corrective measures **K** and evaluating the effectiveness of implementing corrective measures by recalculating the criticality ranks **R** (using accordingly (19), (14) in [1]).

3.6. Systematizing data in a form of a report for all levels of analysis.

4. Choosing a factor change step.

S_{ijk} ($i = \overline{1, n}$, $j = \overline{1, m_i}$, $k = \overline{1, r_{ij}}$) according to (4) in [1]; C_i ($i = \overline{1, b}$) according to (6) in [1]; F_i ($i = \overline{1, l}$) according to (7) in [1]; D_i ($i = \overline{1, p}$) according to (8) in [1]; E_i ($i = \overline{1, q}$) according to (9) in [1]; O_i ($i = \overline{1, r}$) according to (10) in [1]; W_i ($i = \overline{1, s}$) according to (12) in [1]; R_i ($i = \overline{1, w}$) according to (13) in [1]; B_{1j} ($j = \overline{1, z}$) according to (15) in [1]; B_{2j} ($j = \overline{1, x}$) according to (16) in [1]; B_{3j} ($j = \overline{1, c}$) according to (17) in [1]; VK_{ij} ($i = \overline{1, n}$, $j = \overline{1, m_i}$), (see stage 8 of experimental research); K_i ($i = \overline{1, g}$) according to (19) in [1].

5. Analyzing results.

The second step after the approval of the research plan is to determine the amount of experimental research and the necessary software.

The third step is the direct conduct of the experiment; the fourth step is the processing of experimental data, the systematization of all numerical data, the construction of matrices, diagrams and tables.

B. An experimental study of proposed method in aviation

Let's consider in detail step by step of implementation of the proposed method study (one CAIS from each of the categories defined in work [12] are selected):

Stage 1. Identifying system components and setting the level of detail

Step 1.1 For CAIS according to [12], with $n = 3$ considering (1) in [13] we define the complete set of classes of CAIS systems as follows:

$$\mathbf{S}_{\text{CAIS}} = \left\{ \bigcup_{i=1}^3 \mathbf{S}_i \right\} = \{ \mathbf{S}_1, \mathbf{S}_2, \mathbf{S}_3 \} = \{ \mathbf{S}_{\text{ISAO}}, \mathbf{S}_{\text{BSPS}}, \mathbf{S}_{\text{ISAA}} \}, \quad (1)$$

where $\mathbf{S}_1 = \mathbf{S}_{\text{ISAO}}$ is set of information systems of air navigation services; $\mathbf{S}_2 = \mathbf{S}_{\text{BSPS}}$ is set of onboard aircraft information systems; $\mathbf{S}_3 = \mathbf{S}_{\text{ISAA}}$ is set of airline and airport information systems, according to [12].

Step 1.2. For example, with $n = 1$, $m_1 = 5$ while using (2) in [13], we present the set of systems of class \mathbf{S}_1 in the following way:

$$\mathbf{S}_1 = \mathbf{S}_{\text{ISAO}} = \left\{ \bigcup_{j=1}^5 \mathbf{S}_{1j} \right\} = \{ \mathbf{S}_{1.1}, \mathbf{S}_{1.2}, \mathbf{S}_{1.3}, \mathbf{S}_{1.4}, \mathbf{S}_{1.5} \} = \{ \mathbf{S}_{\text{SAE}}, \mathbf{S}_{\text{RZZP}}, \mathbf{S}_{\text{SSP}}, \mathbf{S}_{\text{SOD}}, \mathbf{S}_{\text{SMZ}} \}, \quad (2)$$

where $\mathbf{S}_{1.1} = \mathbf{S}_{\text{SAE}}$ are aviation telecommunication systems; $\mathbf{S}_{1.2} = \mathbf{S}_{\text{RZZP}}$ are radio navigation aids; $\mathbf{S}_{1.3} = \mathbf{S}_{\text{SSP}}$ are surveillance systems; $\mathbf{S}_{1.4} = \mathbf{S}_{\text{SOD}}$ are data processing systems; $\mathbf{S}_{1.5} = \mathbf{S}_{\text{SMZ}}$ are meteorological support systems [12].

Similarly for sets of classes \mathbf{S}_2 and \mathbf{S}_3 , with $n = 2$, $m_2 = 7$ and with $n = 3$, $m_3 = 4$ respectively, while using (2) in [13], we will present the set of systems, where $\mathbf{S}_{2.1} = \mathbf{S}_{\text{SPS}}$ are air signal system; $\mathbf{S}_{2.2} = \mathbf{S}_{\text{SZV}}$ are communication systems; $\mathbf{S}_{2.3} = \mathbf{S}_{\text{NAVS}}$ are navigation systems; $\mathbf{S}_{2.4} = \mathbf{S}_{\text{SSPZ}}$ are collision monitoring and prevention systems; $\mathbf{S}_{2.5} = \mathbf{S}_{\text{OSL}}$ are computing systems of aviation; $\mathbf{S}_{2.6} = \mathbf{S}_{\text{SVI}}$ are information display systems; $\mathbf{S}_{2.7} = \mathbf{S}_{\text{ABSK}}$ are automatic onboard control systems; $\mathbf{S}_{3.1} = \mathbf{S}_{\text{CRS}}$ is computer reservation system; $\mathbf{S}_{3.2} = \mathbf{S}_{\text{GDS}}$ is global reservation system (reservation); $\mathbf{S}_{3.3} = \mathbf{S}_{\text{BSP}}$ is mutual calculations system; $\mathbf{S}_{3.4} = \mathbf{S}_{\text{DCS}}$ are dispatch management systems [12].

The sets of CAIS classes and systems according to [12], with $n = 1, n = 2, n = 3$ and $m_1 = 5, m_2 = 7, m_3 = 4$ taking into account (1) - (2) and (1) in [13] were determined in the following way:

$$\begin{aligned} \mathbf{S}_{\text{CAIS}} &= \{ \mathbf{S}_1, \mathbf{S}_2, \mathbf{S}_3 \} = \{ \mathbf{S}_{\text{ISAO}}, \mathbf{S}_{\text{BSPS}}, \mathbf{S}_{\text{ISAA}} \} = \\ &= \{ \{ \mathbf{S}_{1.1}, \mathbf{S}_{1.2}, \mathbf{S}_{1.3}, \mathbf{S}_{1.4}, \mathbf{S}_{1.5} \}, \{ \mathbf{S}_{2.1}, \mathbf{S}_{2.2}, \mathbf{S}_{2.3}, \mathbf{S}_{2.4}, \mathbf{S}_{2.5}, \mathbf{S}_{2.6}, \mathbf{S}_{2.7} \}, \{ \mathbf{S}_{3.1}, \mathbf{S}_{3.2}, \mathbf{S}_{3.3}, \mathbf{S}_{3.4} \} \} = \\ &= \{ \{ \mathbf{S}_{\text{SAE}}, \mathbf{S}_{\text{RZZP}}, \mathbf{S}_{\text{SSP}}, \mathbf{S}_{\text{SOD}}, \mathbf{S}_{\text{SMZ}} \}, \{ \mathbf{S}_{\text{SPS}}, \mathbf{S}_{\text{SZV}}, \mathbf{S}_{\text{NAVS}}, \mathbf{S}_{\text{SSPZ}}, \mathbf{S}_{\text{OSL}}, \mathbf{S}_{\text{SVI}}, \mathbf{S}_{\text{ABSK}} \}, \{ \mathbf{S}_{\text{CRS}}, \mathbf{S}_{\text{GDS}}, \mathbf{S}_{\text{BSP}}, \mathbf{S}_{\text{DCS}} \} \}. \end{aligned}$$

Step 1.3. To determine subsystem sets, we arbitrarily select one set of systems from each class, for example $\mathbf{S}_{\text{SOD}}, \mathbf{S}_{\text{SSPZ}}, \mathbf{S}_{\text{GDS}}$ and according to (3) in [13] we present subsystem sets with $r_{1.4} = 5, r_{2.4} = 4, r_{3.2} = 18$, and record the obtained data in table 1, where $S_{1.4.1} = S_{\text{ASYPR}}$ are automated air traffic control systems (AATCS); $S_{1.4.2} = S_{\text{SPPP}}$ are automated airspace use planning systems; $S_{1.4.3} = S_{\text{ESAN}}$ are centralized surveillance and distribution systems for the surveillance data of the European Aviation Safety Organization Eurocontrol; $S_{1.4.4} = S_{\text{SOPD}}$ are flight data processing and transmission systems; $S_{1.4.5} = S_{\text{SOAD}}$ are aeronautical information processing and transmission systems; $S_{2.4.1} = S_{\text{TRA}}$ are transponders; $S_{2.4.2} = S_{\text{TCAS}}$ are onboard

collision avoidance systems (TCAS); $S_{2.4.3} = S_{SRPZ}$ are early warning systems for dangerous land rapprochement; $S_{2.4.4} = S_{BMR}$ is airborne radar onboard; $S_{3.2.1} = S_{AMDS}$ is Amadeus; $S_{3.2.2} = S_{TGDS}$ is Travelport GDS; $S_{3.2.3} = S_{SAB}$ is Sabre; $S_{3.2.4} = S_{TRES}$ is TameliaRES; $S_{3.2.5} = S_{APSS}$ is Avantik PSS; $S_{3.2.6} = S_{ABCS}$ is Abacus; $S_{3.2.7} = S_{ACA}$ is AccelAero; $S_{3.2.8} = S_{AXS}$ is Axxess; $S_{3.2.9} = S_{IBE}$ is Internet Booking Engine; $S_{3.2.10} = S_{KUI}$ is KIU; $S_{3.2.11} = S_{MER}$ is Mercator; $S_{3.2.12} = S_{NAV}$ is Navitaire; $S_{3.2.13} = S_{PATH}$ is Patheo; $S_{3.2.14} = S_{RAD}$ is Radixx; $S_{3.2.15} = S_{AKF}$ is Akeflite; $S_{3.2.16} = S_{TTI}$ is Travel Technology Interactive; $S_{3.2.17} = S_{WSMS}$ is WorldTicket Sell-More-Seats; $S_{3.2.18} = S_{SIR}$ is Siren according to [12].

Table 1. Presentation of the subsystems set

System	Value r_{ij}	Subsystems set	Name of subsystems set
S_{SOD}	$r_{1.4} = 5$,	$S_{1.4.1}, S_{1.4.2}, S_{1.4.3}, S_{1.4.4}, S_{1.4.5}$	$S_{ASYPR}, S_{SPPP}, S_{ESAN}, S_{SOPD}, S_{SOAD}$
S_{SSPZ}	$r_{2.4} = 4$,	$S_{2.4.1}, S_{2.4.2}, S_{2.4.3}, S_{2.4.4}$	$S_{TRA}, S_{TCAS}, S_{SRPZ}, S_{BMR}$
S_{GDS}	$r_{3.2} = 18$,	$S_{3.2.1}, S_{3.2.2}, S_{3.2.3}, S_{3.2.4}, S_{3.2.5}, S_{3.2.6},$ $S_{3.2.7}, S_{3.2.8}, S_{3.2.9}, S_{3.2.10}, S_{3.2.11}, S_{3.2.12},$ $S_{3.2.13}, S_{3.2.14}, S_{3.2.15}, S_{3.2.16}, S_{3.2.17}, S_{3.2.18}$	$S_{AMDS}, S_{TGDS}, S_{SAB}, S_{TRES}, S_{APSS}, S_{ABCS},$ $S_{ACA}, S_{AXS}, S_{IBE}, S_{KUI}, S_{MER}, S_{NAV},$ $S_{PATH}, S_{RAD}, S_{AKF}, S_{TTI}, S_{WSMS}, S_{SIR}$

Step 1.4. To determine the set of components, we arbitrarily select one subsystem from each set of subsystems (Table 1), for example $S_{SOAD}, S_{TCAS}, S_{AMDS}$.

For system S_{SOAD} , with $b=7$, while using (4) in [13], we present the set of components in the following way:

$$C_{SOAD} = \left\{ \bigcup_{i=1}^7 C_i \right\} = \{C_1, C_2, \dots, C_7\} = \{C_{ODSS}, C_{OPD}, C_{MKS}, C_{ZVI}, C_{KGZ}, C_{PPR}, C_{ZBP}\},$$

where $C_1 = C_{ODSS}$ is data processing of the surveillance system; $C_2 = C_{OPD}$ is flight data processing; $C_3 = C_{MKS}$ is system monitoring and control; $C_4 = C_{ZVI}$ is recording and reproduction of information; $C_5 = C_{KGZ}$ is commutation of voice communication; $C_6 = C_{PPR}$ is decision support; $C_7 = C_{ZBP}$ is ensuring the safety of flights.

Similarly for systems S_{TCAS} according to [14], and S_{AMDS} according to [15-16], with $b=5$ та $b=4$ while using (4) in [13] respectively, we present the set of components (Table 2), where $C_8 = C_{ANT}$ are antennas; $C_9 = C_{BLO}$ is calculator unit; $C_{10} = C_{VRS}$ is respondent mode S; $C_{11} = C_{IND}$ are indicators (installed in the cockpit); $C_{12} = C_{PYL}$ is control panel; $C_{13} = C_{ATIM}$ is Amadeus Timetable; $C_{14} = C_{AAV}$ is Amadeus availability; $C_{15} = C_{ASCH}$ are Amadeus schedules; $C_{16} = C_{ADA}$ is Amadeus direct access.

Table 2. Presentation of the set of components

System / Subsystem	Set of subsystem components	Value of b	Subsystem components	Name of subsystem components
S_{SOAD}	C_{SOAD}	7	C_1, C_2, \dots, C_7	$C_{ODSS}, C_{OPD}, \dots, C_{ZBP}$
S_{TCAS}	C_{TCAS}	5	C_8, C_9, \dots, C_{12}	$C_{ANT}, C_{BLO}, \dots, C_{PYL}$
S_{AMDS}	C_{AMDS}	4	$C_{13}, C_{14}, \dots, C_{16}$	$C_{ATIM}, C_{AAV}, \dots, C_{ADA}$

Step 1.5. Let us set the minimum level of detail Det_{\min} to describe and decompose the system. The purpose of the analysis S_{ij} / S_{ijk} is to determine the level of criticality of possible types of components interruptions that cause loss of their functionality, to find out their causes, consequences, methods of detection and recommendations for reducing their criticality.

Therefore, the description and decomposition are limited by level “system class” / “system” / “subsystem” / “component” ($S_i / S_{ij} / S_{ijk} / C_i$) and concern only the effects of possible interruptions of certain components C_i . Meaning that $Det_{\min} = C_i$, however, a more detailed study of the more complex components (subsystems) of CAIS may consider the case of $Det_{\min} = C_{ij}$, where C_{ij} are parts of components C_i ($Det_{\min} = S_{ij} \vee S_{ijk} \vee C_i / C_{ij}$) etc.

The selected systems are limited by level $S_{ISAO} / S_{SOD} / S_{SOAD} / C_{SOAD}$; $S_{BSPS} / S_{SSPZ} / S_{TCAS} / C_{TCAS}$; $S_{ISAA} / S_{GDS} / S_{AMDS} / C_{AMDS}$ and concern only the effects of possible interruptions of certain components C_i .

Stage 2. Defining the functions of each detected system component. For system S_{SOAD} , containing a set of components C_{SOAD} , with $l = 15$, while using (5) in [13], we present the set of functions in the following way:

$$F_{SOAD} = \left\{ \bigcup_{i=1}^{15} F_i \right\} = \{F_1, F_2, \dots, F_{15}\} =$$

$= \{F_{OSG}, F_{POI}, F_{VOI}, F_{OPD}, F_{KPOL}, F_{PPAT}, F_{VVI}, F_{DVI}, F_{ZDGZ}, F_{APR}, F_{PZIT}, F_{VPI}, F_{VVKs}, F_{PAP}, F_{ZBP}\}$, where $F_1 = F_{OSG}$ is signal processing; $F_2 = F_{POI}$ is primary information processing; $F_3 = F_{VOI}$ is secondary information processing; $F_4 = F_{OPD}$ is flight data processing; $F_5 = F_{KPOL}$ is flight control; $F_6 = F_{PPAT}$ is air patrol; $F_7 = F_{VVI}$ is display and management of information; $F_8 = F_{DVI}$ is documentation and reproduction of information; $F_9 = F_{ZDGZ}$ is providing air traffic controllers with land and voice communications; $F_{10} = F_{APR}$ is automation of decision making; $F_{11} = F_{PZIT}$ is collision prevention; $F_{12} = F_{VPI}$ is use of planned information; $F_{13} = F_{VVKs}$ is identifying and resolving potential conflict situations; $F_{14} = F_{PAP}$ is aviation events warning; $F_{15} = F_{ZBP}$ is ensuring the safety of flights [12].

Similarly for systems S_{TCAS} according to [14] and S_{AMDS} according to [16], sets of components C_{TCAS} and C_{AMDS} , with $l = 14$ and $l = 4$, while using (5) in [13], we

present sets of functions (Table 3), where $F_{16} = F_{PPR}$ are receiving and transmitting radio waves; $F_{17} = F_{ZIL}$ is request of other aircraft responders; $F_{18} = F_{OMRL}$ is calculating the location of aircraft; $F_{19} = F_{VTL}$ is aircraft trajectory tracking; $F_{20} = F_{PPRD}$ is transmitting warnings and recommendations on the VSI / TRA display or other indicators; $F_{21} = F_{PMPP}$ is the transmission of voice messages to the pilot through the airplane located in the cockpit of the sound notification system; $F_{22} = F_{VNZ}$ is responding to requests in Mode-A, Mode-C and Mode-S from radar systems of the air traffic control service, as well as from other aircraft equipped with TCAS; $F_{23} = F_{ODSS}$ is data exchange with compatible systems; $F_{24} = F_{VPZ}$ is establish a direct connection using a unique address assigned; $F_{25} = F_{PDBV}$ is transfer of data from the barometric height sensor and from the control panel to the TCAS computer unit; $F_{26} = F_{VVI}$ is display of vertical speed indicator (VSI) information with the display of air-condition warnings and recommendations for conflict resolution (TRA); $F_{27} = F_{YRT}$ is setting TCAS mode and responding mode-S; $F_{28} = F_{YKV}$ is setting the UPR radar response codes; $F_{29} = F_{PRS}$ is system operation check; $F_{30} = F_{PIZ}$ is providing (general) flight information on all airlines during the week; $F_{31} = F_{FIPP}$ is generating flight information that has at least one available class for sale or a waiting list; $F_{32} = F_{VGVR}$ is display all scheduled flights; $F_{33} = F_{MODI}$ is the ability to access specific airline information for sale or to complete a waitlist.

Table 3. Presentation of the set of functions

System / Subsystem	Set of subsystem components	Value of l	Functions of components sets	Names of functions of components sets
S_{SOAD}	C_{SOAD}	15	F_1, F_2, \dots, F_{15}	$F_{OSG}, F_{POI}, \dots, F_{ZBP}$
S_{TCAS}	C_{TCAS}	14	$F_{16}, F_{17}, \dots, F_{29}$	$F_{PPR}, F_{ZIL}, \dots, F_{PRS}$
S_{AMDS}	C_{AMDS}	4	$F_{30}, F_{31}, \dots, F_{33}$	$F_{PIZ}, F_{FIPP}, \dots, F_{MODI}$

Stage 3. Determining the list of possible interruptions of each system component. For system S_{SOAD} set of components C_{SOAD} , with $p=9$, while using (6) in [13], we present the set of work interruptions in the following way:

$$D_{SOAD} = \left\{ \bigcup_{i=1}^9 D_i \right\} = \{D_1, D_2, \dots, D_9\} = \{D_{VNIS}, D_{NOPS}, D_{PFOD}, D_{PNI}, D_{VZZ}, D_{NSD}, D_{VRTZ}, D_{VPKS}, D_{VAF}\},$$

where $D_1 = D_{VNIS}$ is detecting a nonexistent signal; $D_2 = D_{NOPS}$ is incorrect estimation of signal parameters; $D_3 = D_{PFOD}$ is data processing and distribution breaches; $D_4 = D_{PNI}$ is suspension of receipt of information on flights of aircraft; $D_5 = D_{VZZ}$ is loss or destruction of a recording device; $D_6 = D_{NSD}$ is unauthorized access to the recording device; $D_7 = D_{VRTZ}$ is loss of radio or telephone communication with crews, related dispatch points and other traffic participants;

$D_8 = D_{\text{VPKS}}$ is the occurrence of potential conflict situations of the PCC; $D_9 = D_{\text{VAF}}$ is detection of an emergency factor [14].

Similarly for systems S_{TCAS} according to [14] and S_{AMDS} according to [15-16], set of components C_{TCAS} and C_{AMDS} , with $p=9$ and $p=17$ respectively, while using (6) in [13], we present the set of work interruptions (Table 4), где $D_{10} = D_{\text{VNA}}$ is directional antenna failure; $D_{11} = D_{\text{VOBS}}$ is failure of the system computing unit; $D_{12} = D_{\text{TCF}}$ is “TCAS FAIL”, if there is a failure of the equipment that is the minimum required for the operation of the TCAS system; $D_{13} = D_{\text{XPF}}$ is “XPNDR FAIL” failure of the respondant mode-S, occurs in the event of termination of the receipt of reliable data on the altitude from the barometric altimeter on the respondant mode-S; $D_{14} = D_{\text{TCO}}$ is “TCAS OFF” (TCAS system is disabled, or problems occur inside the system; $D_{15} = D_{\text{VSF}}$ is “VSI FAIL” (failure of the vertical speed indicator), when the vertical speed arrow is not displayed on the VSI display; $D_{16} = D_{\text{TDF}}$ is “TD FAIL” (failure of air condition indicator) appears when the system TCAS-2000 is unable to display air warnings; $D_{17} = D_{\text{RAF}}$ is “RA FAIL” (refusal to issue RA messages) appears when TCAS system is unable to display recommendations for resolving a conflict situation; $D_{18} = D_{\text{NPY}}$ is malfunction or failure of the control panel; $D_{19} = D_{\text{ZSD}}$ is failure to update dates (periods); $D_{20} = D_{\text{NIPA}}$ is incompleteness of information about airlines; $D_{21} = D_{\text{NZI}}$ is providing outdated information; $D_{22} = D_{\text{NNI}}$ is unreliability of the information provided; $D_{23} = D_{\text{NIMP}}$ is failure to provide landing information (only schedule is displayed, regardless of availability); $D_{24} = D_{\text{VMPK}}$ is the inability to buy a ticket unless the airline has an agreement to sell with Amadeus; $D_{25} = D_{\text{NZD}}$ is inability to find airline information to alert you to potential threats or to obtain necessary information.

Table 4. Presentation of sets of work interruptions

System / Subsystem	Set of subsystem components	Value of p	Work interruptions	Names of work interruptions
S_{SOAD}	C_{SOAD}	9	D_1, D_2, \dots, D_9	$D_{\text{VNIS}}, D_{\text{NOPS}}, \dots, D_{\text{VAF}}$
S_{TCAS}	C_{TCAS}	9	$D_{10}, D_{11}, \dots, D_{18}$	$D_{\text{VNA}}, D_{\text{VOBS}}, \dots, D_{\text{NPY}}$
S_{AMDS}	C_{AMDS}	7	$D_{19}, D_{20}, \dots, D_{25}$	$D_{\text{ZSD}}, D_{\text{NIPA}}, \dots, D_{\text{NZD}}$

Stage 4. Determining the consequences of each possible work interruption. For each possible work interruption of the set D_{SOAD} with $q=10$, while using (7) in [13], we present the set of interruption consequences in the following way:

$$\mathbf{E}_{\text{SOAD}} = \left\{ \bigcup_{i=1}^{10} E_i \right\} = \{E_1, E_2, \dots, E_{10}\} = \{E_{\text{NPR}}, E_{\text{PRSY}}, E_{\text{VVPS}}, E_{\text{VRLP}}, E_{\text{NODD}}, E_{\text{VRTZ}}, E_{\text{PRVZ}}, E_{\text{VNM}}, E_{\text{ZPS}}, E_{\text{PRS}}\},$$

where $E_1 = E_{\text{NPR}}$ is wrong decision-making, due to incorrect analysis of the air situation; $E_2 = E_{\text{PRSY}}$ is malfunction of control systems, power supply,

communication, piloting, lack of fuel, interruptions in the life support of the crew and passengers, failure of engines, destruction of individual aircraft structures; $E_3 = E_{VVPS}$ is lack of ability to track aircraft; $E_4 = E_{VRLP}$ is loss of opportunity to investigate a flight incident FI; $E_5 = E_{NODD}$ is inability to evaluate the actions of the operator; $E_6 = E_{VRTZ}$ is no radio or telephone connection; $E_7 = E_{PRVZ}$ is violation of recommendations on solving the collision threat; $E_8 = E_{VNM}$ is choosing the wrong maneuver; $E_9 = E_{ZPS}$ are aircraft collisions; $E_{10} = E_{PRS}$ is malfunction of control systems, power supply, communication, piloting, lack of fuel, interruptions in the life support of the crew and passengers, failure of engines, destruction of individual aircraft structures [14].

Similarly, for each possible work interruption of sets \mathbf{D}_{TCAS} according to [14] and \mathbf{D}_{AMDS} according to [16], with $q = 3$ and $q = 6$ respectively, while using (7) in [13], we present the set of work interruptions (Table 5), where $E_{11} = E_{NVVP}$ is TCAS 2000 system may be temporarily unable to determine the relative bearing of the conflicting aircraft due to the large roll angle, which causes the directional antenna to shade; $E_{12} = E_{NVP}$ is inability to display recommendations for conflict resolution; $E_{13} = E_{NVPY}$ is inability to use the control panel accordingly; $E_{14} = E_{NRS}$ is system inability to work in real time; $E_{15} = E_{VIA}$ is lack of information on airlines; $E_{16} = E_{NOOI}$ is inability to get online flight booking information; $E_{17} = E_{MZGP}$ is a possible malfunction in the flight schedule or the need to reformat it; $E_{18} = E_{VPZD}$ are problems with refueling, the possibility of a collision threat; $E_{19} = E_{NSP}$ is lack of awareness of employees, which could lead to the wrong decision.

Table 5. Presentation of the sets of work interruptions

Work interruption	Value of q	Work interruption consequences	Names of work interruption consequences
\mathbf{D}_{SOAD}	10	E_1, E_2, \dots, E_{10}	$E_{NPR}, E_{PRSY}, \dots, E_{PRZ}$
\mathbf{D}_{TCAS}	3	E_{11}, E_{12}, E_{13}	$E_{NVVP}, E_{NVP}, E_{NVPY}$
\mathbf{D}_{AMDS}	6	$E_{14}, E_{15}, \dots, E_{19}$	$E_{NRS}, E_{VIA}, \dots, E_{NSP}$

Stage 5. Identifying signs of work interruption detection. For possible work interruptions \mathbf{D}_{SOAD} , while using (8)-(9) in [13], with $r = 0$ (the selected set of interruptions of work did not show any sign O_i), and for the set \mathbf{D}_{TCAS} , according to [14] and \mathbf{D}_{AMDS} , according to [15-16], with $r = 1$ and $r = 3$ respectively, while using (8)-(9) in [13], we present the set of signs of work interruption detection (Table 6) in the following way (3):

$$\mathbf{O} = \left\{ \bigcup_{i=1}^4 O_i \right\} = \{O_1, O_2, \dots, O_4\} = \{O_{VSI}, O_{TIM}, O_{AUS}, O_{SCH}\}, \quad (3)$$

where $O_1 = O_{\text{VSI}}$ is VSI/TRA display; $O_2 = O_{\text{TIM}}$ is Timetable (general schedule screen); $O_3 = O_{\text{AUS}}$ is Amadeus Access Update/Amadeus Access Sell; $O_4 = O_{\text{SCH}}$ is Schedule (schedule screen).

Taking into account (9) in [13], $E(O_{\text{VSI}}, D_i) = E(O_{\text{TIM}}, D_i) = E(O_{\text{AUS}}, D_i) = E(O_{\text{SCH}}, D_i) = 1$.

Table 6. Presentation of the set of signs of work interruption detection

Work interruption	Value of r	Work interruption consequences	Names of work interruption consequences
\mathbf{D}_{TCAS}	1	O_1	O_{VSI}
\mathbf{D}_{AMDS}	3	O_2, O_3, O_4	$O_{\text{TIM}}, O_{\text{AUS}}, O_{\text{SCH}}$

Stage 6. Identifying ways of detecting work interruptions. For each possible work interruption of the set \mathbf{D}_{SOAD} according to [13], \mathbf{D}_{TCAS} according to [14] and \mathbf{D}_{AMDS} according to [15], while using (10) in [13], with $s = 7, s = 1, s = 1$ respectively, we present the set of ways of detecting work interruptions (Table 7) in the following way:

$$\mathbf{W}_{\text{SOAD}} = \left\{ \bigcup_{i=1}^9 W_i \right\} = \{W_1, W_2, W_3, W_4, W_5, W_6, W_7, W_8, W_9\} = \{W_{\text{SAZS}}, W_{\text{SOPD}}, W_{\text{ASAZ}}, W_{\text{BBRP}}, W_{\text{SGZ}}, W_{\text{AZS}}, W_{\text{SZBP}}, W_{\text{TCAS}}, W_{\text{AAIR}}\} \quad (4)$$

where $W_1 = W_{\text{SAZS}}$ is automatic dependent surveillance systems; $W_2 = W_{\text{SOPD}}$ is flight data processing system (FDPS); $W_3 = W_{\text{ASAZ}}$ are automated aviation security systems; $W_4 = W_{\text{BBRP}}$ are on-board multi-channel “black box” flight recorders; $W_5 = W_{\text{SGZ}}$ are voice communication systems; $W_6 = W_{\text{AZS}}$ are automated surveillance, communications, information processing and on-board collision avoidance systems; $W_7 = W_{\text{SZBP}}$ are flight safety systems; $W_8 = W_{\text{TCAS}}$ are TCAS system; $W_9 = W_{\text{AAIR}}$ is Amadeus AIR.

Table 7. Presentation of the set of ways to detect interruptions

Work interruption	Value of s	Work interruption consequences	Names of work interruption consequences
\mathbf{D}_{SOAD}	7	W_1, W_2, \dots, W_7	$W_{\text{SAZS}}, W_{\text{SOPD}}, \dots, W_{\text{SZBP}}$
\mathbf{D}_{TCAS}	1	W_8	W_{TCAS}
\mathbf{D}_{AMDS}	1	W_9	W_{AAIR}

Stage 7. Construction of a three-dimensional criticality matrix. For the system S_{SOAD} we form a criticality table according to such parameters as “probability – weight – number of interruptions of system operation” and construct a three-dimensional criticality matrix (Fig. 1 a). Similarly, for systems S_{TCAS} and S_{AMDS} we

form a criticality table and construct a three-dimensional matrix (Fig. 1 b and Fig. 1 c, respectively).

Stage 8. Calculation of the criticality rank of probable interruptions

Step 8.1. For the S_{SOAD} system, work interruptions $D_1 = D_{VNIS}$, let's define an indicator B_{1j} (frequency assessment) as (13) in [13], where value of z is going to be found according to table 5 in [1]. Thus let's define an indicator $B_1 = 5$. Similarly, for every possible work interruption of S_{SOAD} , S_{TCAS} and S_{AMDS} systems, let's define an indicator B_{1j} as (13) in [13], table. 5 in [1] and add obtained figures to the report (stage 11, table 11).

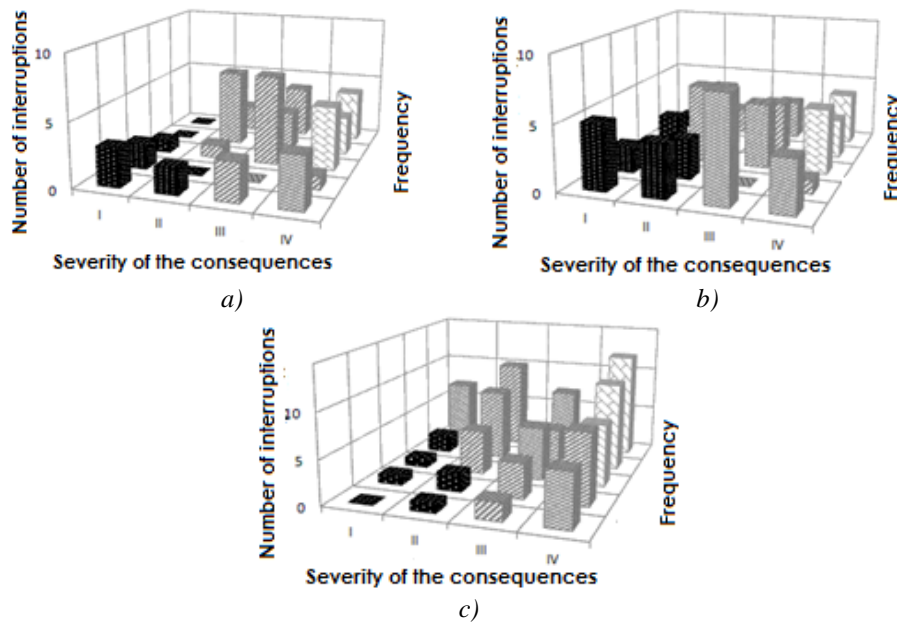


Fig. 1. Three-dimensional criticality matrix for S_{SOAD} (a), S_{TCAS} (b) and S_{AMDS} (c)

Step 8.2. For the S_{SOAD} system, work interruptions $D_1 = D_{VNIS}$, let's define an indicator B_{2j} (probability assessment of D_i component detection of C_i before it's appearance) as (14) in [13], where x value is found similarly according to table 7 in [1]. Therefore, let's define an indicator $B_2 = 4$. Similarly, for every possible interruption of systems S_{SOAD} , S_{TCAS} and S_{AMDS} , let's define an indicator B_{2j} as (14) in [13], table 7 in [1] and add obtained figures to the report (stage 11, table 11).

Step 8.3. For the S_{SOAD} system, work interruptions $D_1 = D_{VNIS}$, let's define an indicator B_{3j} (weight assessment of D_i component of C_i) as (15) in [13], where c value is found similarly according to table 9 in [1]. Therefore, let's define an indicator $B'_3 = 7$. Similarly, for every possible interruption of S_{SOAD} , S_{TCAS} and

S_{AMDS} systems, let's define an indicator B'_3 as (15) in [13], table 9 in [1] and add obtained figures to the report (stage 11, Table 11).

Stage 8.4. Calculation of values for the weighting coefficients of work interruption consequences. Mentioned coefficients are introduced according to [18].

Step 8.4.1. For example, for the weighting coefficients of work interruption consequences according to [18], having $n = 7$ considering (16) in [13], let's define a complete set of criteria of weighting coefficients as follows (5):

$$\mathbf{VK} = \left\{ \bigcup_{i=1}^7 \mathbf{VK}_i \right\} = \{ \mathbf{VK}_1, \mathbf{VK}_2, \dots, \mathbf{VK}_7 \} = \{ \mathbf{VK}_{KZG}, \mathbf{VK}_{EKON}, \mathbf{VK}_{VNNS}, \mathbf{VK}_{POLN}, \mathbf{VK}_{MZT}, \mathbf{VK}_{TRV}, \mathbf{VK}_{VSKI} \}, \quad (5)$$

where $\mathbf{VK}_1 = \mathbf{VK}_{KZG}$ is number of citizens involved (health and social consequences); $\mathbf{VK}_2 = \mathbf{VK}_{EKON}$ is economic effect; $\mathbf{VK}_3 = \mathbf{VK}_{VNNS}$ is impact on the environment; $\mathbf{VK}_4 = \mathbf{VK}_{POLN}$ is political implications; $\mathbf{VK}_5 = \mathbf{VK}_{MZT}$ is territorial reach; $\mathbf{VK}_6 = \mathbf{VK}_{TRV}$ is duration; $\mathbf{VK}_7 = \mathbf{VK}_{VSKI}$ is interdependence of sectors CI (the consequence of the destruction of one is the destruction of the others) according to [18].

It also should be noted that, criteria of weighting coefficients of work interruption consequences are placed from most important – “7” to least important – “1”.

Step 8.4.2. For example, if $n = 1$, $m_1 = 5$ using (17) in [13], let's represent the set of coefficients \mathbf{VK}_1 as follows:

$$\mathbf{VK}_1 = \mathbf{VK}_{KZG} = \left\{ \bigcup_{j=1}^5 \mathbf{VK}_{1j} \right\} = \{ \mathbf{VK}_{1.1}, \mathbf{VK}_{1.2}, \mathbf{VK}_{1.3}, \mathbf{VK}_{1.4}, \mathbf{VK}_{1.5} \} = \{ \mathbf{VK}_{0-5}, \mathbf{VK}_{6-20}, \mathbf{VK}_{D100}, \mathbf{VK}_{D499}, \mathbf{VK}_{B500} \},$$

where $\mathbf{VK}_{1.1} = \mathbf{VK}_{0-5}$ is 0-5 deceased; $\mathbf{VK}_{1.2} = \mathbf{VK}_{6-20}$ is 6-20 deceased; $\mathbf{VK}_{1.3} = \mathbf{VK}_{D100}$ is 21-100 deceased; $\mathbf{VK}_{1.4} = \mathbf{VK}_{D499}$ is 101-499 deceased; $\mathbf{VK}_{1.5} = \mathbf{VK}_{B500}$ is ≥ 500 according to [18].

Similarly, for sets of coefficients $\mathbf{VK}_2, \mathbf{VK}_3, \dots, \mathbf{VK}_7$, if $n = \overline{2, 7}$ and $m_2 = m_3 = m_4 = m_5 = 5$ accordingly, using (17) in [13] let's represent all sets of coefficients and add them to the table 8, where $\mathbf{VK}_{2.1} = \mathbf{VK}_{D100M}$ is < 100 mil.; $\mathbf{VK}_{2.2} = \mathbf{VK}_{D499M}$ is 100-499 mil.; $\mathbf{VK}_{2.3} = \mathbf{VK}_{D2,9M}$ is 500 mil. – 2,9 bil.; $\mathbf{VK}_{2.4} = \mathbf{VK}_{D6,9M}$ is 2,9 bil. – 6,9 bil.; $\mathbf{VK}_{2.5} = \mathbf{VK}_{B7M}$ is > 7 bil.; $\mathbf{VK}_{3.1} = \mathbf{VK}_{MIG}$ is < 1 ha. or 0,0001% of water resources; $\mathbf{VK}_{3.2} = \mathbf{VK}_{D10G}$ is 1-10 ha, or 0,0001-0,001 % of water resources; $\mathbf{VK}_{3.3} = \mathbf{VK}_{D100G}$ is 10-100 ha, or 0,001-0,01 % of water resources; $\mathbf{VK}_{3.4} = \mathbf{VK}_{D1000G}$ is 100-1000 ha, or 0,01 - 0,1 % of water resources; $\mathbf{VK}_{3.5} = \mathbf{VK}_{B1000G}$ is > 1000 ha, or $> 0,1$ % of water resources; $\mathbf{VK}_{4.1} = \mathbf{VK}_{MIN}$ is minimal; $\mathbf{VK}_{4.2} = \mathbf{VK}_{SOCN}$ is social discontent; $\mathbf{VK}_{4.3} = \mathbf{VK}_{MITG}$ are rallies, protests; $\mathbf{VK}_{4.4} = \mathbf{VK}_{MASZ}$ are riots; $\mathbf{VK}_{4.5} = \mathbf{VK}_{REV}$ are revolutions, wars; $\mathbf{VK}_{5.1} = \mathbf{VK}_{OBYD}$ is separate building; $\mathbf{VK}_{5.2} = \mathbf{VK}_{SEL}$ is village; $\mathbf{VK}_{5.3} = \mathbf{VK}_{RGN}$ is district, city; $\mathbf{VK}_{5.4} = \mathbf{VK}_{OBL}$

is region; $VK_{5.5} = VK_{DER}$ is country; $VK_{6.1} = VK_{DGOD}$ is less than an hour; $VK_{6.2} = VK_{DOBA}$ is day; $VK_{6.3} = VK_{3DOB}$ are 3 days; $VK_{6.4} = VK_{5DOB}$ are 5 days; $VK_{6.5} = VK_{10DIB}$ are 10 days; $VK_{7.1} = VK_{MVID}$ is almost no; $VK_{7.2} = VK_{NVR}$ are causes no destruction; $VK_{7.3} = VK_{VRIS}$ are causes destruction of one sector; $VK_{7.4} = VK_{VR2S}$ are causes destruction of two sectors; $VK_{7.5} = VK_{VR3S}$ are causes destruction of three and more sectors [18].

Table 8. Sets of coefficients representation

Weighting coefficients	Coefficients' names	Value m_i	Set of coefficients	Names' of sets of coefficients
VK_1	VK_{KZG}		$VK_{1,1}, VK_{1,2}, VK_{1,3}, VK_{1,4}, VK_{1,5}$	$VK_{0-5}, VK_{6-20}, VK_{D100}, VK_{D499}, VK_{B500}$
VK_2	VK_{EKON}		$VK_{2,1}, VK_{2,2}, VK_{2,3}, VK_{2,4}, VK_{2,5}$	$VK_{D100M}, VK_{D499M}, VK_{D2,9M}, VK_{D6,9M}, VK_{B7M}$
VK_3	VK_{VNNS}		$VK_{3,1}, VK_{3,2}, VK_{3,3}, VK_{3,4}, VK_{3,5}$	$VK_{MIG}, VK_{D10G}, VK_{D100G}, VK_{D1000G}, VK_{B1000G}$
VK_4	VK_{POLN}	5	$VK_{4,1}, VK_{4,2}, VK_{4,3}, VK_{4,4}, VK_{4,5}$	$VK_{MIN}, VK_{SOCN}, VK_{MITG}, VK_{MASZ}, VK_{REV}$
VK_5	VK_{MZT}		$VK_{5,1}, VK_{5,2}, VK_{5,3}, VK_{5,4}, VK_{5,5}$	$VK_{OBYD}, VK_{SEL}, VK_{RGN}, VK_{OBL}, VK_{DER}$
VK_6	VK_{TRV}		$VK_{6,1}, VK_{6,2}, VK_{6,3}, VK_{6,4}, VK_{6,5}$	$VK_{DGOD}, VK_{DOBA}, VK_{3DOB}, VK_{5DOB}, VK_{10DIB}$
VK_7	VK_{VSKI}		$VK_{7,1}, VK_{7,2}, VK_{7,3}, VK_{7,4}, VK_{7,5}$	$VK_{MVID}, VK_{NVR}, VK_{VRIS}, VK_{VR2S}, VK_{VR3S}$

Step 8.4.3. For the S_{SOAD} system, work interruptions $D_1 = D_{VNIS}$, indicator $B_3 = 7$, and value of weighting coefficient as (19) in [13], is calculated as follows:

$$VK_{VNIS} = \frac{1}{7} \left(\frac{28}{35} + \frac{18}{30} + \frac{5}{25} + \frac{16}{20} + \frac{15}{15} + \frac{4}{10} + \frac{5}{5} \right) = \frac{24}{35} \approx 0,7,$$

hence, according to (18) in [13] $B'_3 = 0,7 \cdot 7 = 4,9 \approx 5$.

Similarly, for every possible work interruption of S_{SOAD} , S_{TCAS} and S_{AMDS} systems, let's calculate values B'_3 taking into account weighting coefficients VK_i , and add obtained figures to the Table 9 and report (stage 11, Table 11).

Table 8. Calculation of weighting coefficients values

System / Subsystem	Value p	Name	Calculated value VK_i	Value B'_3	Value B_3
S_{SOAD}	9	$VK_{VNIS}, VK_{NOPS}, \dots, VK_{VAF}$	$0,7; 0,7; 0,7; 0,8; 0,6;$ $0,7; 0,8; 0,7; 0,6$	$7; 8; 9; 8; 8;$ $8; 9; 9; 8$	$5; 6; 6; 6; 5;$ $6; 7; 6; 5$
S_{TCAS}	9	$VK_{VNA}, VK_{VOBS}, \dots, VK_{NPY}$	$0,7; 0,8; 0,8; 0,8; 0,8;$ $0,8; 0,7; 0,8; 0,8$	$9; 8; 7; 7; 9;$ $7; 8; 9; 7$	$6; 6; 6; 7; 7;$ $6; 6; 7; 6$
S_{AMDS}	7	$VK_{ZSD}, VK_{NIPA}, \dots, VK_{NZD}$	$0,6; 0,6; 0,7; 0,7;$ $0,7; 0,6; 0,7$	$8; 5; 5; 8;$ $6; 6; 5$	$6; 3; 4; 6;$ $4; 4; 4$

Step 8.5. Assessment of criticality rank of R_i each of work interruption types listed D_i according to (12) in [13]. For example, for the S_{SOAD} system, work interruption $D_1 = D_{VNIS}$, let's calculate the criticality rank $R_1 = 5 \cdot 4 \cdot 5 = 100$ and add obtained figures to the report (stage 11). Similarly, for every possible work interruption of systems S_{SOAD} , S_{TCAS} and S_{AMDS} , let's calculate interruptions criticality rank and add obtained figures to the report (stage 11, Table 11).

Stage 9. Selection of the list of the most significant (critical) work interruptions. For the S_{SOAD} system, work interruptions $D_1 = D_{VNIS}$, calculated interruptions criticality rank $R_1 = 5 \cdot 4 \cdot 5 = 100$, according to the criticality determination rule (20) in [13], $D_1 = D_{VNIS}$ refers to the *Middle* level, requires the development of corrective measures to reduce criticality rank. Obtained figures are highlighted in the report (stage 11, Table 11) with the help of various colours, if D_i , according to (20) in [13], refers to the *High* criticality level, then R_i in Table 11 is highlighted in black, if D_i refers to the *Middle* level – in grey, if D_i refers to the *Low* level – in light grey.

Similarly, for every possible work interruption of S_{SOAD} , S_{TCAS} and S_{AMDS} systems, let's rank calculated values of criticality level as (20) in [13] and add obtained figures to the report (stage 11, Table 11). Moreover, on this stage a Pareto bar chart (Fig. 2) is used to spot the list of most significant (critical) D_i .

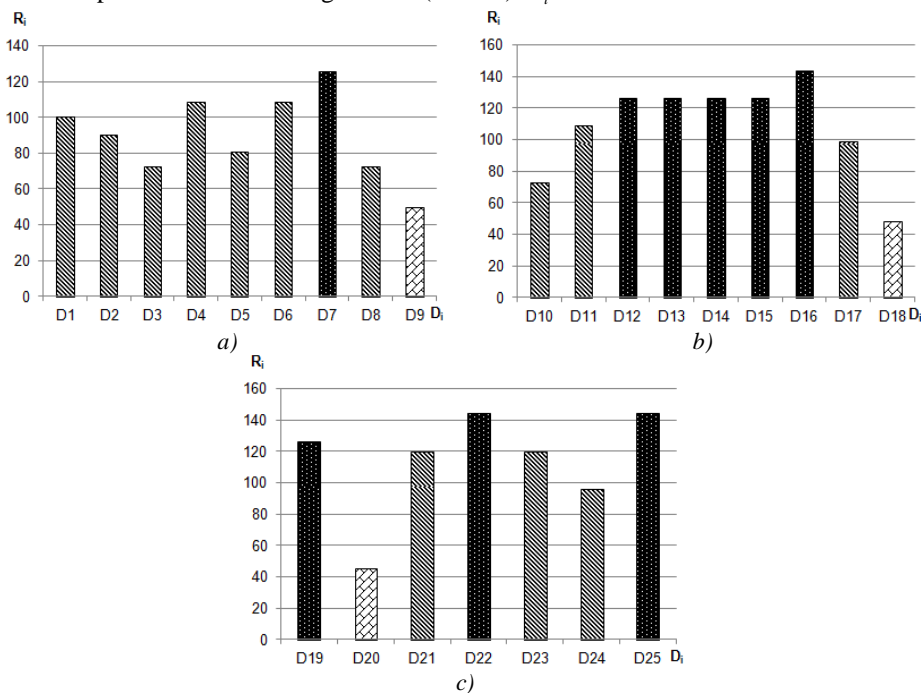


Fig. 2. Calculation results of R_i for S_{SOAD} (a), S_{TCAS} (b) and S_{AMDS} (c)

The diagram is created separately for each S_{ij} (to rank the most significant (critical) D_i , hence D_i are placed on the horizontal axis, and calculated values R_i are on the vertical axis (like (12) in [13]), if $R_i > R_k$, then D_i is highlighted in black on the diagram, if $R_0 < R_i \leq R_k$ – then D_i is highlighted in grey, if $R_i \leq R_0$ – then D_i is highlighted in light grey. Paterno bar charts help spot the list of most significant (critical) work interruptions. They also make it possible to compare separate systems by the calculated criticality rank and to identify the system which is the most critical among CAIS. For the S_{SOAD} system, the most critical work interruption is D_7 , rank criticality calculations, carried out by (12) in [13], revealed the following result: $R_7 = 3 \cdot 6 \cdot 7 = 126 > R_k = 125$. For the S_{TCAS} system the most critical work interruption are values $D_{12} - D_{16}$, rank criticality calculations, carried out by (12) in [13], revealed the following result: $R_{12} = R_{13} = R_{14} = R_{15} = 126 > R_k = 125$; $R_{16} = 144 > R_k = 125$. For the S_{AMDS} system most critical work interruptions are D_{19}, D_{22}, D_{25} rank criticality calculations, carried out by (12) in [13], revealed the following result: $R_{19} = 126 > R_k = 125$; $R_{22} = R_{25} = 144 > R_k = 125$. Paterno bar charts also made it possible to compare the number of critical work interruptions of studied systems and found out that S_{TCAS} system is the most critical.

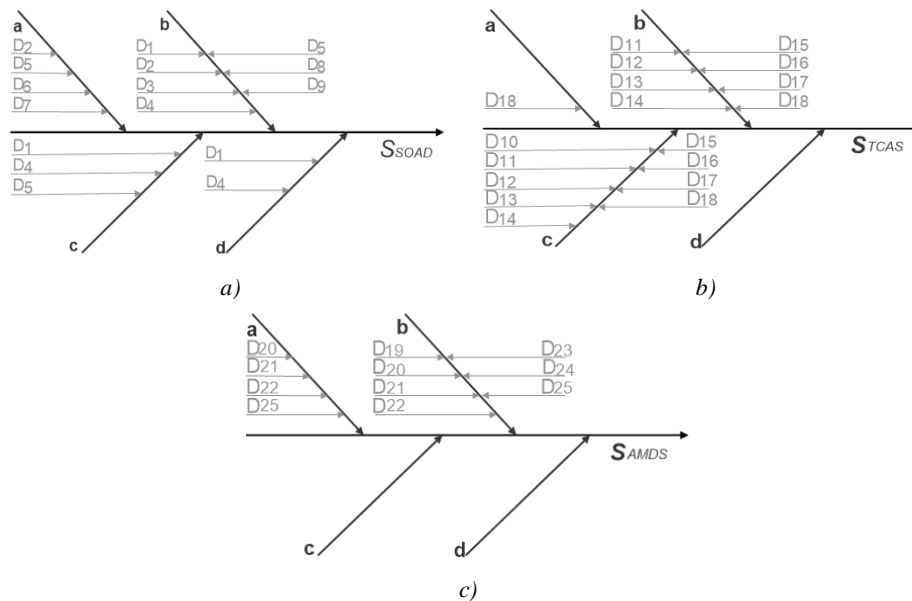


Fig. 3. Ishikawa cause and effect diagram for S_{SOAD} (a), S_{SOAD} (b) and S_{AMDS} (c)

Stage 10. Forming a list of corrective measures. To make a list of corrective measures for S_{SOAD} , S_{TCAS} and S_{AMDS} systems let's create Ishikawa cause and effect

diagrams [17, 19] (Fig. 3), that graphically reflect the characteristics that cause work interruptions D_i and increase the effectiveness of corrective measures development.

Ishikawa cause and effect diagrams for selected systems has divided all identified D_i by the main causes of their occurrence, namely due to errors of: users (a), software (b), hardware (c), network technologies (d). Therefore, priority areas for developing corrective measures for S_{SOAD} and S_{AMDS} systems are elimination of software errors causes and user errors (b and a on Fig. 3 a and Fig. 3 c), for S_{TCAS} system – elimination of hardware and software related causes (b and c on Fig. 3 b).

Whereafter for every possible work interruption of S_{SOAD} , S_{TCAS} and S_{AMDS} systems, if $g = 3, g = 2, g = 1$ accordingly, using (21) in [13], let's represent a set of methods to detect interruptions (that correspond to *High* and *Middle* according to rule (20) in [13],) as follows:

$$\mathbf{K} = \left\{ \bigcup_{i=1}^6 K_i \right\} = \{K_1, K_2, \dots, K_6\} = \{K_{PONA}, K_{OROB}, K_{OKPD}, K_{ZRTO}, K_{POBR}, K_{VOAA}\}, \quad (6)$$

where $K_1 = K_{PONA}$ is directional antenna inspection and repair; $K_2 = K_{OROB}$ is inspection and repair of system's computer unit, $K_3 = K_{OKPD}$ are scheduled review and repair of data transmission channels; $K_4 = K_{ZRTO}$ is change of maintenance and repair regulations; $K_5 = K_{POBR}$ is scheduled review of flight recorders; $K_6 = K_{VOAA}$ are Amadeus AIR components update as scheduled.

Table 20. The list of corrective measures

S_{ij} / S_{ijk}	D_i	R_{begin}	K_i	R_{finish}
S_{SOAD}	D_1	100	K_{OKPD}	$5 \cdot 3 \cdot 5 = 75$
	D_2	90	K_{OKPD}	$3 \cdot 4 \cdot 6 = 72$
	D_3	72	K_{ZRTO}	$3 \cdot 3 \cdot 6 = 54$
	D_4	108	K_{OKPD}	$3 \cdot 5 \cdot 6 = 90$
	D_5	80	K_{POBR}	$2 \cdot 7 \cdot 4 = 56$
	D_6	108	K_{POBR}	$3 \cdot 5 \cdot 6 = 90$
	D_7	126	K_{ZRTO}	$3 \cdot 5 \cdot 7 = 105$
	D_8	72	K_{OKPD}	$3 \cdot 4 \cdot 6 = 72$
S_{TCAS}	D_{10}	72	K_{PONA}	$3 \cdot 3 \cdot 6 = 54$
	D_{11}	108	K_{OROB}	$3 \cdot 5 \cdot 6 = 90$
	D_{12}	126	K_{OROB}	$3 \cdot 6 \cdot 6 = 108$
	D_{13}	126	K_{OROB}	$3 \cdot 6 \cdot 6 = 108$
	D_{14}	126	K_{OROB}	$3 \cdot 5 \cdot 7 = 105$
	D_{15}	126	K_{OROB}	$3 \cdot 7 \cdot 5 = 105$

S_{AMDS}	D_{16}	144	K_{OROB}	$4 \cdot 5 \cdot 6 = 120$
	D_{17}	98	K_{OROB}	$2 \cdot 7 \cdot 7 = 98$
	D_{19}	126	K_{VOAA}	$3 \cdot 6 \cdot 6 = 108$
	D_{21}	120	K_{VOAA}	$4 \cdot 5 \cdot 4 = 80$
	D_{22}	144	K_{VOAA}	$4 \cdot 5 \cdot 6 = 120$
	D_{23}	120	K_{VOAA}	$4 \cdot 5 \cdot 4 = 80$
	D_{24}	96	K_{VOAA}	$2 \cdot 6 \cdot 4 = 48$
	D_{25}	144	K_{VOAA}	$5 \cdot 6 \cdot 4 = 120$

The list of necessary corrective measures for S_{SOAD} , S_{TCAS} and S_{AMDS} systems, is presented in Table 10. The effectiveness of corrective measures assessment is carried out by recalculation of R_i (stage 8). Next, we use the initial value R_{begin} (R_i before the K_i implementation) and final R_{finish} (R_i after the implementation of K_i): if $R_{finish} < R_k$ then corrective measures aimed to reduce the rank of criticality can be recommended for use to provide cybersecurity [20].

In Table 10 we can see which corrective measures can be implemented and for how much they reduce criticality rank (D_i highlighted in grey are those that became insignificant *Low*, while D_i highlighted in light grey are those that shifted from *High* to *Middle* criticality rank as a result of corrective measures implementation).

Stage 11 – Report generation. At this stage, data obtained in the previous stages ($S_i, S_{ij}, C_i, F_i, D_i, E_i, O_i, W_i$ та R_i) is systematized, visualization of qualitative and calculation of quantitative values of CAIS criticality is carried out. The stage involves the systematization of all information in the form of a table. An example of report creation for S_{SOAD} , S_{TCAS} and S_{AMDS} systems is presented in Table 11.

Table 31. Report for all levels of analysis

S_i / S_{ij} $/ S_{ijk}$	C_i	F_i	D_i	E_i	O_i	W_i	R			
							B_1	B_2	B_3	R_i
$S_{1,4,5}$	C_1	F_1	D_1	E_1	0	W_1	5	4	5	100
	C_2	F_2	D_2	E_2	0	W_1	3	5	6	90
	C_3	F_3	D_3	E_3	0	W_2	3	4	6	72
	C_4	F_4	D_4	E_4	0	W_3	3	6	6	108
	C_5	F_5	D_5	E_5	0	W_4	2	8	5	80
	C_6	F_6	D_6	E_6	0	W_4	3	6	6	108
	C_7	F_7	D_7	E_7	0	W_5	3	6	7	126
		F_8	D_8	E_8	0	W_6	3	4	6	72

		F_9	D_9	E_9	0	W_7	2	5	5	50
		...		E_{10}						
		F_{15}								
$S_{2,4,2}$	C_8	F_{16}	D_{10}	E_{11}	$O_1 = 1$	W_8	3	4	6	72
	C_9	F_{17}	D_{11}	E_{12}	$O_1 = 1$	W_8	3	6	6	108
	C_{10}	F_{18}	D_{12}	E_{13}	$O_1 = 1$	W_8	3	7	6	126
	C_{11}	F_{19}	D_{13}		$O_1 = 1$	W_8	3	7	7	126
	C_{12}	F_{20}	D_{14}		$O_1 = 1$	W_8	3	6	7	126
		F_{21}	D_{15}		$O_1 = 1$	W_8	3	7	6	126
		F_{22}	D_{16}		$O_1 = 1$	W_8	4	6	6	144
		F_{23}	D_{17}		$O_1 = 1$	W_8	2	7	7	98
		F_{24}	D_{18}		0	W_8	2	4	6	48
		...								
		F_{29}								
$S_{3,2,1}$	C_{13}	F_{30}	D_{19}	E_{14}	$O_2 = 1$	W_9	3	7	6	126
	C_{14}	F_{31}	D_{20}	E_{15}	$O_2 = 1$	W_9	3	5	3	45
	C_{15}	F_{32}	D_{21}	E_{16}	$O_2 = 1$	W_9	5	6	4	120
	C_{16}	F_{33}	D_{22}	E_{17}	$O_3 = 1$	W_9	4	6	6	144
			D_{23}	E_{18}	$O_4 = 1$	W_9	5	6	4	120
			D_{24}	E_{19}	0	W_9	4	6	4	96
			D_{25}		$O_3 = 1$	W_9	6	6	4	144

5 Discussion

Thereby, Table 11 summarizes such information results of the proposed method as: a list of system components, their functions, types of interruptions for each component of the system; information on the causes and consequences of interruptions for each component of the system; calculations of criticality rankings, anking results are a list of the most significant (critical) interruptions of work, which are displayed in a formalized and convenient for experts form. Other output data was obtained at different stages of the method implementation: criticality matrix, which according to the collected preliminary data graphically reflects the criticality of the system components (stage 7); Pareto diagram which shows the level of criticality inside the system and makes it possible to compare several different systems (stage 9); Ishikawa's cause and effect diagram that allows to identify priority areas for developing appropriate corrective measures (stage 10).

Experimental study gives a possibility to determine the importance level of S_{SOAD} (aeronautical information processing and transmission system), S_{TCAS} (onboard

collision avoidance system, TCAS) and S_{AMDS} (system Amadeus) systems in aviation and defined components of these CAIS particularly:

- system S_{SOAD} has one critical component C_7 with one functional interruption D_7 ;
- system S_{TCAS} has three critical components C_{10} , C_{11} and C_{12} with five functional interruptions $D_{12} - D_{16}$;
- system S_{AMDS} has two critical components C_{13} and C_{16} with three functional interruptions D_{19} , D_{22} , D_{25} .

Three-dimensional criticality matrix and Paterno bar charts shows that S_{TCAS} system is the most critical among selected CAIS (5 critical interruptions).

Ishikawa cause and effect diagrams shows that priority areas for developing corrective measures for S_{SOAD} and S_{AMDS} systems are elimination of software errors causes and user errors, for S_{TCAS} system – elimination of hardware and software related causes.

Conclusions

In this paper experimental study of proposed by authors FMECA-based method for importance level assessing of the CII objects in aviation was carried out. It was selected three CAIS from different categories (air navigation systems, aircraft on-board information systems as well as airlines and airports systems): S_{SOAD} (aeronautical information processing and transmission system), S_{TCAS} (onboard collision avoidance system, TCAS) and S_{AMDS} (Amadeus system).

Three-dimensional criticality matrix as well as Paterno bar charts shows that S_{TCAS} system is the most critical among selected CAIS (5 critical interruptions and 3 critical components). Ishikawa cause and effect diagrams shows that priority areas for developing corrective measures for S_{SOAD} and S_{AMDS} systems are elimination of software errors causes and user errors, but for S_{TCAS} system – elimination of hardware and software related causes.

In the future research study it is planned to develop software that, based on the proposed method, will allow to conduct an experimental research and confirm the possibility of determining the importance of different categories of CAIS as well as to assess infrastructure in different industries.

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Case-Based and Project-Based Methods for Effective E-learning in ICT Safety and Security

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Abstract. The objective of this paper is to develop a practical E-learning framework with implementation of case method and project-based learning. In paper we obtain the following results. Content of the massive open online course (MOOC) “Safety and Security of Control Systems” is analyzed. This MOOC was introduced in 2017 for master students program “Cybersecurity” at National Aerospace University “KhAI” (Kharkiv, Ukraine). A core part of this MOOC is a project devoted to safety and security assessment of real systems and software. Taxonomy for indicators of E-learning effectiveness is proposed. Case study was done in Ukraine between students of Cybersecurity program after finish of study of the MOOC “Safety and Security of Control Systems”. A sample includes 40 master students involved in the course learning during 2017-2019. Case study results confirmed a set of hypotheses related with E-learning effectiveness when case method and project-based learning are implemented.

Keywords: case method, E-learning, homework, learning efficiency, MOOC, project-based learning.

1 Introduction

Online learning also named as electronic learning (E-learning) means 100% virtual education via internet media with support of information technologies (IT). E-learning entails a huge transformation of education which becomes more and more distance as well as personalized. A modern approach to E-learning implementation is consists in development of massive open online courses (MOOCs). Despite numerous well known advantages and disadvantages of E-learning we put emphasis on the challenges and opportunities related with application of this relatively new education technology, such as: individual approaches to students with opportunities to build individual learning trajectories based in student-oriented approach [1]; application of Learning Management System (LMS) as centralized environment for administration, documentation, tracking, reporting, and delivery of learning courses [2]; needs in essential scope of relevant studies and data, that would provide a strong background for empirical based analysis [3]; choice of relevant indicators to make qualitative and quantitative assessment of E-learning [4]; high degree of importance of students’ homework which can be organized in both individual and collaborative manner [5]; needs in

choice of effective teaching methods depending on features of courses and sciences; in the paper we discuss the case method [6] as well as the project-based learning [7] applied for the course devoted to safety and security of control systems [8].

It is needed to notice concerning some gaps in researches devoted to the above points. The actual research is directed to fulfill some of these gaps. Based on the above, we develop a concept for our research area (Fig. 1). This concept recognizes dramatic importance of students' homework for successful implementation of the whole E-learning process. After that, we take into account learning course defendant features and discuss in this paper the course "Safety and Security of Control Systems" [9] which is provided since 2017 by the Department of Computer Systems, Networks and Cybersecurity of National Aerospace University "KhAI" (Kharkiv, Ukraine). Also, we discuss the additional values which are provided by application of the case method as well as project-based learning for E-learning.

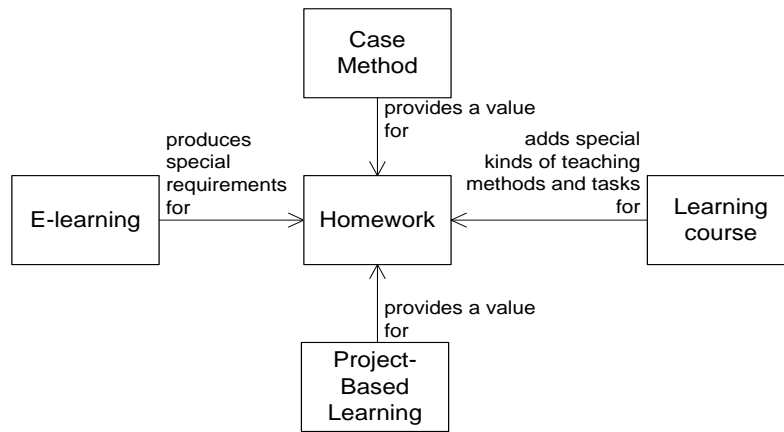


Fig. 1. A Concept of the paper: an influence of a learning course, the case method and the project-oriented approach to homework during E-learning

2 Literature Review

In our literature review we mainly orient to STEM (Science, Technology, Engineering and Mathematics). Also, based on our paper concept (Fig. 1), we include in our review scope researches related with E-learning homework, case method and project-oriented approach.

The purpose of homework is to teach a student to meaningfully and independently work first with educational material, then with scientific information, to lay the foundations of self-organization and self-education in order to instill the ability to continuously improve their skills [10]. Homework can include individual and group activities carried out under the indirect guidance of a teacher during classroom and extra-curricular activities, stimulating cognitive activity, developing intellectual abilities and needs of the individual in self-education. Modern approach to homework is important because the focus is changed from passive teaching to active self-education. LMSs support students' homework with a set of tools such as quiz and tests, a forum,

a glossary and a wiki section, links to additional resources and webinars. Many studies known did not demonstrate the expected correlation between time spent on homework and students' academic achievement [11]. It means homework effectiveness is highly dependent from a manner of its organization. However, the homework organizational principles are insufficiently represented in existing researches. Also we found big contradictions in arguing, is group homework more effective than individual homework or vice versa [12].

Case method or case study means the analysis of realistic economic, managerial and other situations (cases) in order to teach participants certain skills during the discussion of the case, including through the training of other participants [13]. Firstly Case Method was implemented at Harvard Business School in the 1920s [14]. At that time, teachers were faced with the problem of the lack of actual business manuals. The way was found as a description of specific situations from the practice of real companies. The cases as simplified descriptions of problematic business situations were offered to students, and students had to find and substantiate solutions. From the field of business education case method was extended to social sciences and STEM [15]. Since 1990-s case method was started to apply in the post-soviet countries. It is worth to mention a fundamental work "The Case Study Method: Anatomy and Application" [16] published in Kyiv in 2002.

The most part researchers agreed there a number of advantages of case method application for education such as orientation to students' individuality, development of entrepreneurial and managerial skills as well as problem-solving abilities and critical thinking, increasing motivation for learning, active involvement in the educational process, getting experience of team work and communication, decision making in conditions of stress and uncertainty [17].

The most of the studies in area of case method are traditionally devoted to business education [18], and we put emphasis on needs of experience transfer from business education to technical education. So there are not many papers demonstrated case method application for the STEM domain, but between the known papers we pay attention to the few following researches.

Case method is used for teaching in automobile design course at some Chinese colleges [19]. Only some qualitative assessments are provided in the paper. The conclusion is case method positively affects students' understanding of material, creates a positive and creative atmosphere during teaching sessions, as well as permits to create to lectures high quality interdisciplinary curriculum. Russian studies related to the use of case method in chemistry have shown an increase in student achievement and professional self-awareness [20], which coincides with the results obtained for entrepreneurial education [21].

There are some empirical studies, which do not confirm effectiveness of case method application in education. For example, the paper [22] explores hypotheses about the impact of case studies and other teaching methods (lectures and business simulations, which means working with an interactive model of the economic system) on the development of skills such as problem solving, interpersonal communication, and professional identity. This study shows that business simulation is more effective, than case method from the point of view of development students' skills.

One more important issue is a set of indicators which are used for case method effectiveness assessment as well as for education effectiveness assessment as whole.

Such indicators include indicators determined by teachers and indicators determined by students [23]. It should be noted that, in our opinion, the assessment of the learning process by students only is quite subjective, since students do not fully possess information about the actual usefulness of the acquired skills and knowledge.

The case method is also used to conduct scientific research in the conditions of the impossibility of collecting data sufficient to perform statistical analysis [24], when, firstly, it is necessary to analyze the object or phenomenon directly in the context of its development, secondly, it is impossible to control the environment in which the object is located or a phenomenon occurs, and thirdly, the number of instances insufficient for static analysis is observed. A comparative analysis of the main approaches to the implementation of the epistemological and methodological aspects of the case method was performed in [25], while the case method allows combining quantitative and qualitative research methods [26]. For example, the cases in the study provide a descriptive representation of three innovative career and technical education programs in energy management and alternative energy programs at the U.S. community college level [27].

Project-based learning (PBL) is aimed at training students to use the acquired knowledge and skills, and most importantly to be able to solve real professional tasks. Project training usually runs in parallel with the main schedule and helps students transfer knowledge and skills from classes to the real work environment in which they plunge during the project activity [28]. Advantages of PBL are very similar with advantages of case method. There is active and creative learning of students, facing of real life and real professional work, a positive impact on student motivation, training in teamwork skills and in project management [29]. At the same time it is a huge challenge for students and teachers, which can be pretty unusual and hire extra efforts.

Researchers state some important features of PBL, like the following [30]. PBL projects are central, not peripheral to the curriculum, so students learn the fundamentals of disciplined via the project. Projects involve students in investigations that provoke the transformation and construction of knowledge. Projects are student-driven and do not end up at a predetermined results since students are provided with more autonomy than usually. Project should be realistic in difference with usual school exercises. For example, the [31] describes a case study devoted to implementation software development on the agile base between software engineering students. Results of the case demonstrate essential improvement of understanding agile development process. A conclusion is the most part of students became ready for employment at software development companies.

3 Objective and tasks

Based on the performed literature review, we recognize some gaps in area of research related with case-based and project-based E-learning. These gaps are in the area of some lack of empirical data as well as a lack of theoretical basis for development of MOOC supported with PBL and the case method. The objective of this paper is to develop a practical E-learning framework with implementation of case method and PBL. To achieve the paper objective we perform the following research steps:

- Firstly, we analyze theoretical and practical content of the MOOC “Safety and Security of Control Systems”;
- Secondly, we propose taxonomy for indicators of E-learning effectiveness;
- After that, we do setting a field questioner based study of experience of students involved in E-learning of the MOOC “Safety and Security of Control Systems”;
- Finally we develop a practical E-learning framework with implementation of case method and PBL.

4 Analysis of the MOOC “Safety and Security of Control Systems”

The MOOC “Safety and Security of Control Systems” was introduced in 2017 for master students program “Cybersecurity” by the Department of Computer Systems, Networks and Cybersecurity at National Aerospace University “KhAI” (Kharkiv, Ukraine). The goal was initially to make the course as a problem solving, so it is aimed at solving a practical problem: preparing for safety assessment against the requirements of the standard IEC 61508 “Functional safety of electrical/ electronic/ programmable electronic safety-related systems” or other similar safety standards. Another purpose of this course was to make it fit for industrial training.

Thus, the course participants received the whole set of advantages of MOOC users, like learning with small information blocks, study at a convenient time, if a student did not understand something or missed, then he “scroll through” it again, etc. In the subject area, the benchmark was made primarily for Industrial Control Systems (ICS), but other control system architectures are also considered like embedded systems, and Internet of Things (IoT). A look at security was directed from the point of view of safety assurance. However, where appropriate, a relation between safety and security is demonstrated, for example, a common life cycle of safety and security. It was considered which techniques of safety assurance can increase the level of security.

The course includes six lectures or, in MOOC terminology, six weeks of study. Primary, the lectures were posted on the YouTube channel in the form of the following playlists (see Fig. 2): Lecture 1. Introduction; Lecture 2. Requirements of safety standards; Lecture 3. Functional safety management; Lecture 4. Safety and security life cycle; Lecture 5. Quantitative assessment of safety; Lecture 6. Techniques and measures of safety assurance.

Every lecture is supported with a set of 5-10 minutes videos in quantity from four to seven per one lecture as well as with lecture slides and homework items. Students’ homework includes the following items: video lectures and slides of lecture for independent learning of theory; answer to test questions (quiz); reading of recommended literature, including literature included in the curriculum specially for mandatory individual learning; study of additional materials exceeding the scope of the course program; the course project, which is the most important part of the course practicum.

The course learning contains the following techniques: asynchronous interactive learning with video lectures during a primary study of theoretical material; self-paced independent learning with slides of lectures and recommended literature during a deep study of theoretical material; collaborative learning during implementation of the course project (Fig. 3); synchronous learning during consultancy leaded by a teacher.

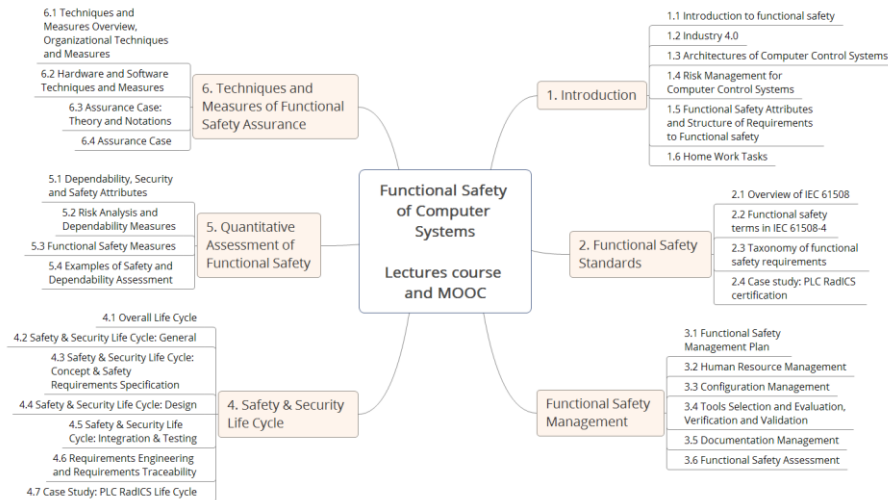


Fig. 2. Structure of the MOOC “Safety and Security of Control Systems”

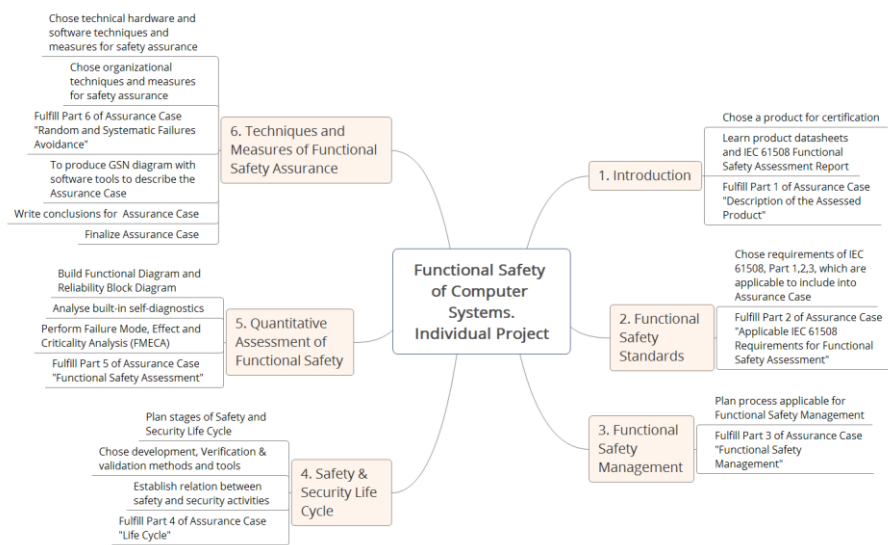


Fig. 3. Structure of the Assurance Case template for performance of the course project

The course project performance is the main objective and result of the course learning. First of all, the project is necessary to solve an applied problem based on the acquired knowledge. The main task of the project is to develop a document covering the analysis and assessment of safety and security related with the lecture material. This document is called the Assurance Case in accordance with the actual practice of safety and security assessment [8]. The development of the Assurance Case is now used in the practice of assessment and certification against safety and security re-

quirements. The components of ICS like controllers, actuators and sensors are offered as subjects of assessment. Students are given the Assurance Case template, and they fill it out in stages, based on the material in each lecture. During the project implementation we assign project teams with two, three or four students depending from their preferences. The structure of the Assurance Case template associated with the lecture content for the course project performance is represented on Fig. 3.

5 Taxonomy of E-Learning Effectiveness Indicators

The proposed three-level taxonomy of E-learning effectiveness indicators is presented in Table 1. This taxonomy is a good starting point to analyze the known empirical researches, but also the taxonomy can be enriched by results of new experiments.

Table 1. Taxonomy of E-learning effectiveness indicators

Stakeholder who defines indicators	Group of indicators	Example of indicators
Teachers	Students' knowledge assessment	Performance assessment metrics
		Results of passing of tests and exams
		General results of studies at the university
	Students' soft skills assessment	Soft skills assessment metrics
		Abilities to follow E-learning
Self-assessment	Abilities to drive E-learning	
	Satisfaction with E-learning	
	Process and LMS assessment	Process and LMS assessment metrics
Students	Self-assessment	Abilities to follow E-learning
		Satisfaction with E-learning
	Process and LMS assessment	Process and LMS assessment metrics
	Teachers' assessment	Abilities to drive E-learning
	The influence on the development of competencies	Influence on the theory understanding
Influence on the development of hard / soft skills		
Opportunities of applying the competencies in practice	The influence on the development of hard / soft skills	
Graduates	Degree of satisfaction with the former educational process	Quality of the working environment
		Salary
	Opportunities of applying the competencies in practice	The influence on the actual hard / soft skills
Employers	Satisfaction with the employees' results	Key Performance Indicators (KPIs)
		Salary

Researches, which are analyzed above, deal mainly with the education performance indicators defined by teachers and students in the learning process. It should be noted that assessment of the learning process by students is quite subjective, since students do not fully possess objective information about the actual usefulness of the acquired skills and knowledge. The same applies to some extent to teachers. Complaints about the lag of teachers' experience from life's realities are justified in many cases. Therefore, if teachers are working in the framework of the curriculum only, they can also not always fully appreciate the objective usefulness of the knowledge and skills taught. Therefore, in our opinion, it is necessary to take into account two more important categories of indicators. The first category is effectiveness indicators determined by graduates during some time after the end of the graduation, and the second category is effectiveness indicators determined by the employer. A challenge is to take valid and relevant data to estimate these kinds of indicators, but modern online technology can help to resolve this issue.

6 Case Study of E-learning Effectiveness

Our research setting is Ukrainian National Aerospace University "KhAI". Computer Systems, Networks and Cybersecurity Department introduced a new education program "Cybersecurity" in 2017. During 2017-2019, four groups of master students have been graduated in accordance with the Cybersecurity program. One of the courses of this program, named "Safety and Security of Control Systems" was provided on completely E-learning basis as a MOOC with use YouTube for video files disposition as well as Google Drive for distribution of all other course materials.

A non-random sample covers all general population of 40 students, which is presented in Table 2 with gender details. It should be noticed that in 2017 we taught two groups of students because the Cybersecurity program update and shifting of the considered MOOC to other semester. The groups of students were 8 to 12 people, so it was easy to distribute and to collect the study questionnaire since individual communications have been established between teacher and students.

Table 2. A sample of students for study

	2017(1)	2017(2)	2018	2019	Total
Male	9	10	8	7	34 (85%)
Female	3	2	0	1	6 (15%)
Together	12	12	8	8	40

Study design is based on a set of the following hypotheses related with E-learning effectiveness (see Fig. 4): Hypothesis 1 (H1): Students are satisfied with E-learning process; Hypothesis 2 (H2): Students prefer E-learning format faster than traditional format; Hypothesis 3 (H3): Theoretical E-learning materials can be presented in a form which is understandable for students; Hypothesis 4 (H4): Practical E-learning exercises can be presented in a form which is understandable for students; Hypothesis 5 (H5): E-learning motivates students to get new knowledge.

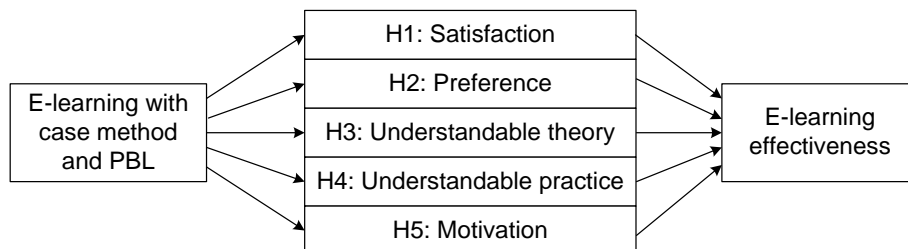


Fig. 4. A structure of the hypotheses network

All students were asked to fulfill the questionnaire after the end of the course study. The questionnaire contains five parts related with five stated hypotheses. Five-degree scale is used to estimate students' agreement with the questionnaire statements. Also we asked students to indicate the positive issues of the course as well as the issues which can be improved. For this part we calculate quantity of students who are agree with one or the other statement. One student can choose more than one statement. Results of the study are presented in Table 3. We also include average exam grades in ECTS points to Table 3.

Results of review confirmed the truth of the hypotheses H1-H5. An average satisfaction degree is 4.2, so H1 "Students are satisfied with E-learning process" is confirmed. An average confidence level for E-learning preference is 4.1, so H2 "Students prefer E-learning format faster than traditional format" is confirmed. An average understanding level of the lecture materials is 4.0, so H3 "Theoretical E-learning materials can be presented in a form which is understandable for students" is confirmed. An average understanding level of the project materials is 3.9, so H4 "Practical E-learning exercises can be presented in a form which is understandable for students" is confirmed. We notice, the degree for project materials understanding is the lowest because the project is really the most difficult and challenging part of the course. An average motivation degree is 4.3, so H5 "E-learning motivates students to get new knowledge" is confirmed. All ratings from students are in the range from 3.8 to 4.5 what mean a low level of the dispersion.

An average exam degree is 77.7. Three groups of students got high level degree more than 80 on the average, and only the second group at 2017 got 64.3, what affect dramatically the degree for all four groups.

The most important issues for students are opportunities to be free in a choice of a place and a time of study (80% of respondents). After that students emphasize the importance of a new view for security issues (62.5%), availability of all the course materials at one place (57.5%), and an opportunity to drive a real world project (47.5%). The main concern of students is a lack of teacher support (90% of respondents). Concerning this point it is worth to notice, that it is the main challenge which face students during E-learning, and also this is the main difference between E-learning and traditional "face-to-face" learning. We understand a lack of the self-driven behavior is a big challenge during the project performance. It is also highlighted with other students' issues such as the requests for more detailed steps for the project implementations (82.5%) and for more transparent expectations and acceptance criteria for the project (67.5).

Table 3. Results of case study

	2017(1)	2017(2)	2018	2019	Average
Satisfaction level for the course learning	4.5	4.0	4.1	4.2	4.2
E-learning format is better for me than traditional (confidence level)	4.3	3.9	4.2	4.0	4.1
Understandability of the lecture materials	4.1	3.9	4.0	4.2	4.0
Understandability of the project materials	3.9	3.8	4.0	4.1	3.9
Motivation for self-learning	4.4	4.1	4.5	4.4	4.3
Exam degree (ECTS)	84.2	64.3	83.1	82.5	77.7
Positive issues of the course					Total
Opportunity to study at any place at any time	10	9	6	7	32 (80%)
A new view for security issues	8	5	5	7	25 (62.5%)
Availability of all the course materials at one place	7	6	4	6	23 (57.5%)
Opportunity to drive a real world project	5	3	6	5	19 (47.5%)
Improvement points of the course					Total
More teacher support	11	10	8	7	36 (90%)
More detailed steps for the project implementations	12	10	6	5	33 (82.5%)
More explanations for the lecture materials	8	7	7	6	28 (70%)
More transparent expectations and acceptance criteria for the project	10	8	5	4	27 (67.5%)
Do provide the project subjects from software engineering area	5	4	1	3	13 (32.2%)

We continue to work for more transparent and understandable project descriptions. The degree of project material understandability increased from 3.8-3.9 in 2017 to 4.1 in 2019. The same, the number of students who need more explanations for the project steps decreased from 12 (100%) in 2017 to 5 (62.5%) in 2019, and the number of students who expect more transparency and acceptance criteria decreased from 10 (83.3%) in 2017 to 5 (33.3%) in 2019. It is also important for students to have the project subject in the field related with the students' experience in software engineering (32.5%), including ICS and IoT.

7 E-learning Framework with Case Method and Project-Based Learning

An integral part of this research joints all outputs in a view of E-learning framework supported with case method and PBL. This framework is presented on Fig. 5 Below we briefly discuss the main parts of the framework.

PBL principles are related with approach to choose and drive the project as the core practical activity of the course. We adopt the approach proposed in [30] with the following principles:

- Projects are the central item of the course and the central teaching strategy, because students learn the course via the project;
- Projects involve students in a special kind of investigation directed to knowledge construction and transformation;
- Students play the main role in projects performance, and projects are realistic.

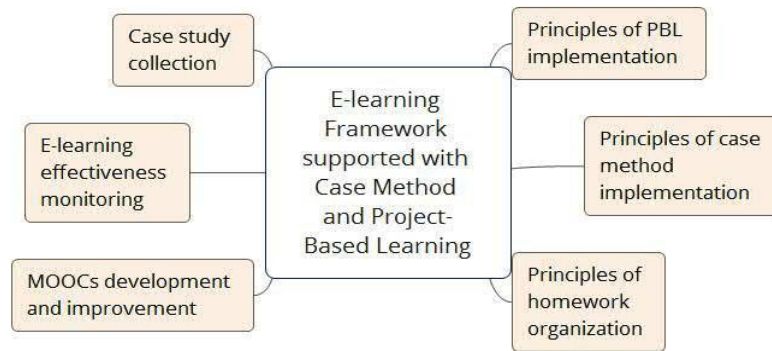


Fig. 5. A structure of the E-learning framework supported with case method and PBL

Principles of case method implementation are close related with PBL approach. The main idea is to propose for students a real software-hardware product and real documents covering safety and security assessment and assurance. Successful case method implementation suggests consideration of all best practices related with PBL and homework organization.

Homework organization includes supplying of students with all materials and instructions. Principles of homework are the following: collection of online materials in the LMS area; combination, depending on the material being studied, of various forms of homework (such as classroom individual or group study, extracurricular individual or group study); student-centered approach with the formation of an individual trajectory of the education and homework depending on the individual preferences of students and the recommendations of teachers; focus aimed at the development of creative and research competencies; monitoring by teacher in order to analyze adoption of learning material by students; analysis of the opportunities to improve the homework process; taking into account curriculums of other interrelated academic courses.

MOOCs development and improvement bases on using of the modern design tools and LMS. Other MOOCs related issues lay in students feedback monitoring and continuous improvement. For E-learning effectiveness monitoring teachers should choose a set of appropriate effectiveness indicators. An example of taxonomy is presented in Table 1. Results of effectiveness monitoring are outputs of a case study organized to supply stakeholders with relevant empirical data. Periodical field review can be a method to implement a case study. Also other relevant case study can be included in data collection to support cases meta-analysis.

8 Conclusions

Twenty years after beginning of intensive implementation of E-learning we continue to follow technologies rather than theory like “the cart has been placed before the horse” [32]. However, pedagogic innovations are such important like technological innovations especially, if a lack of students’ motivation is founded.

In this paper we obtain the following results. Content of the MOOC “Safety and Security of Control Systems” is analyzed. This MOOC was introduced in 2017 for master students program “Cybersecurity” by the Department of Computer Systems, Networks and Cybersecurity at National Aerospace University “KhAI” (Kharkiv, Ukraine). A core part of this MOOC is a project devoted to safety and security assessment of real systems and software.

Taxonomy for indicators of E-learning effectiveness is proposed. This taxonomy contain three the following levels: stakeholder who defines indicators including teachers, students, graduates and employers, group of indicators and single indicators.

Case study was done in Ukraine between students of Cybersecurity program after finish of study of the MOOC “Safety and Security of Control Systems”. A sample includes 40 master students involved in the course learning during 2017-2019. Case study confirmed a set of hypotheses related with E-learning effectiveness when case method and PBL are implemented. We found the truth of five hypotheses, H1-H5 (see Fig. 4).

Also we checked the main issues which increase or decrease quality of E-learning. The students’ opinion is the most important advantage of E-learning is an opportunity to be free in a choice of a place and a time of study (80% of respondents). After that students emphasize the importance of a new view for security issues (62.5%), availability of all the course materials at one place (57.5%), and an opportunity to drive a real world project (47.5%). Students are concerned about a lack of teacher support (90%), needs for more detailed explanation concerning steps of the project implementations (82.5%) and more explanations for the lecture materials (70%), more transparent expectations and acceptance criteria for the project (67.5) and more the project subjects from software engineering area (32.2%)

Finally, we develop a practical E-learning framework with implementation of case method and PBL, which includes the following entities: principles of PBL implementation, principles of case method implementation, principles of homework organization, MOOCs development and improvement, E-learning effectiveness monitoring, and case study collection. A practical value of the paper is determined by development of a framework for effective E-learning implementation based on the principles

of PBL and case method. A theoretical novelty of the paper lies in a technique of E-learning effectiveness analysis supported with new experimental data.

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Technique for Cyberattacks Detection Based on DNS Traffic Analysis

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Abstract. Today, with the rapid spread of computer systems and information technology, as well as their integration into the global Internet, cyberattacks and malware are one of the main types of cybercrime. The damage they cause when they infect network hosts can range from a slight increase in outbound traffic to a complete network malfunction or loss of critical data. The paper presents a new technique for cyberattacks detection based on DNS traffic analysis. It enables the proactive malicious requests detecting in corporate area networks based on DNS protocol, and is aimed to identify and block the malicious domains and DND data deletion requested by the attackers.

The process of malicious requests detection is based on the use of "isolation forest" algorithm, which allows to detect the anomalies in DNS data exchange.

Based on the general data deletion scheme, an anomaly of DNS traffic is observed when it is used for data exchange.

The anomaly in the DNS traffic is detected due to analysis of the set of features concerning the requests and responses that may indicate the attack presence in the network.

Keywords: Cyberattack, DNS, Network traffic, Network, Isolation forest, Cybersecurity, Computer system, Host, Malicious traffic, Attacks Detection

1 Introduction

One of the main signs of the society development is the growth of dependence on the quality and reliability of computer systems used in all fields of human activity. The corresponding strengthening of the strategic orientation of information resources necessitates the increase of requirements to the level of the cybersecurity. However, there are cases of violations of the information security system. The problem is exacerbated by the fact that the peculiarities of the global network and the Internet allow attackers to implement long-term, massive cyberattacks on critical infrastructure, and the timely application of adequate security measures is greatly hindered by the imperfection of attack detection systems.

The development of information technology necessitates the growth of vulnerabilities, threats and cyberattacks to various computer systems. According to resources devoted to the prevention, detection and removal of malware and spam report about the great number of new cyberattacks [1, 2]. One of the ways to infect the computer systems is the usage of the public DNS servers as they are employed for faster web browsing or censorship bypassing and are open to anyone. Such situation requires the development of a new more efficient techniques and approaches for the cyberattacks detection based on DNS traffic analysis [3-5].

2 Related works

Today, a number of techniques are developed for the detection of cyberattacks which use the DNS traffic.

In [6] a DNS Anomaly Detection Visual Platform, provides a novel visualization that depicts on-line DNS traffic, and a one-class classifier that deals with traffic anomaly detection, is presented. Due to the highly dynamic nature of DNS traffic, a proposed classification method continuously updates what counts as normal behavior; it has been successfully tested on synthetic attacks, with an 83% of the area under the curve.

In [7] the technique for MitM-attacks detection called DNSwitch is described. The utility is able to detect a DNS-spoofing type attack.

In [8] an efficient detection method of suspicious DNS traffic by resolver separation per application program is presented. Based on that almost all kinds of software including malware use DNS name resolution, in the proposed method, the DNS queries will be forwarded to different DNS full resolver per application program. The DNS queries from unknown application programs can be detected since there will be only little DNS traffic need to be analyzed compare to the whole network traffic. The evaluation results confirmed that the proposed method can precisely forward the DNS queries based on the application programs correctly.

In [9] a new filtering approach called "The Gunner System". The approach involves rule-based Domain Name System (DNS) features for detecting botnets.

In [10] a method for detecting malware infected computers by monitoring unintended DNS traffic on wireless networks by collaboration with DHCP server. By deploying the proposed system on campus wireless networks, computers within DHCP configured environment can be detected when they are infected by some types of malware and it attempts to communicate with the corresponding C&C servers using DNS protocol. In [11] a study aimed to detect and reduce the effects of DNS amplification attacks in SDN-based with the developed system. This system aims to monitor the variations in the amplification factor and TTL header to initiate mitigation and sustain the victim's life. It also ensures that legitimate packets are not suspected in the process. In doing so, it is aimed to generate alarms and mitigation by using the central management feature of SDN, by writing the metrics into a time series database immediately. Experimental results show that this system can be used SDN-based networks and prevent an attack in reactively.

In [12] an IoT router that verifies the DNS traffic originated from IoT devices and performs the detection of IoT devices that are consulting unauthorized DNS servers is proposed. In [13] a state-of-the-art of systems that utilized passive DNS traffic for the purpose of detecting malicious behaviors on the Internet is presented. The paper demonstrates the feasibility of the threat detection prototype through real-life examples, and provide further insights for future work toward analyzing DNS traffic in near real-time. In [14] a system REMeDy that assists operators to identify the use of rogue DNS resolvers in their networks. REMeDy is a completely automatic and parameter-free system that evaluates the consistency of responses across the resolvers active in the network. It operates by passively analyzing DNS traffic and, as such, requires no active probing of third-party servers. REMeDy is able to detect resolvers that manipulate answers, including resolvers that affect unpopular domains.

In [15] the issue of DNS-based data exfiltration proposing a detection and mitigation method leveraging the Software-Defined Network (SDN) architecture is presented. Popular DNS data exfiltration attacks and current exfiltration detection mechanisms are analyzed to generate a feature-set for DNS data exfiltration detection. The DNSxD application is presented and its performance evaluated in comparison with the current exfiltration detection mechanisms.

Paper [16] proposes a method to detect two primary means of using DNS for malicious purposes. The machine learning models to detect information exfiltration from compromised machines and the establishment of command & control servers via tunneling are developed and validated. It is able to detect a malware used in several recent APT attacks.

In [17] a targeted DNS spoofing attack that exploits a vulnerability present in DHCP server-side IP address conflict detection technique to prevent a genuine DHCP server from offering network parameters is proposed. Paper discusses how proposed attack can target even a single victim client also without affecting other clients.

The Domain Name System Security Extensions (DNSSEC) is a specification which provides extensions and modifications that add data origin authentication and data integrity to the Domain Name System. But DNSSEC extension has a number of disadvantages and limitations and has seen poor deployment thus far and not intended to prevent a wide range of cyberattacks with usage of DNS [18-19].

The mentioned above methods for the malicious DNS traffic detecting demonstrated the limitation of the types of the network attacks' detection, as the involve not enough features of the malicious traffic behavior. On the other hand, mentioned techniques have in some cases low detection efficiency and high false positives.

That why there is strong need in new for the cyberattacks detection techniques based on DNS traffic analysis.

3 Technique for Cyberattacks Detection Based on DNS Traffic Analysis

In order to solve mentioned problems, a new technique for cyberattacks detection based on DNS traffic analysis is proposed. It enables the proactive malicious requests

detecting in corporate area networks based on DNS protocol, and is aimed to identify and block the malicious domains and DND data deletion requested by the attackers.

The method is based on detecting anomalies in DNS data exchange.

An anomaly of DNS traffic is observed when attacks use them for data exchange. It is suggested that domains used to exchange data through DNS protocol are characterized by the set of features concerning the requests and responses that may indicate the attack presence in the network. Detection of attacks, that use DNS traffic, is based on the analysis of a certain domain.

The process of malicious requests detection is based on the use of "isolation forest" algorithm, which allows the anomalies detection [20] and consists of two main phases: training and detection.

The training phase includes the following steps:

1. Knowledge formation about benign requests by the users, which use the DNS data exchange, based on benign traffic samples.
2. Knowledge presentation as the set of feature vectors.
3. Construction of the "isolated trees" structures based on the feature vectors of based on benign traffic samples.
4. Passing through the "isolated trees" structures for each benign traffic samples in the test set, and calculation of the "anomaly score" using the isolated forest algorithm.

The detection phase includes the steps:

1. Monitoring of the network in order to gather the features that may indicate the attack presence.
2. Formation of the set of feature vectors.
3. Defining as an "anomaly" the feature vector whose estimation exceeds a predetermined threshold, depending on the domain to which the analysis is applied.
4. Blocking the execution of malicious requests in the computer system.

The method allows its implementation in DNS servers, which are not necessarily intended for detection, as long as they support DNS traffic logging and domain black-listing (as shown in fig. 1).

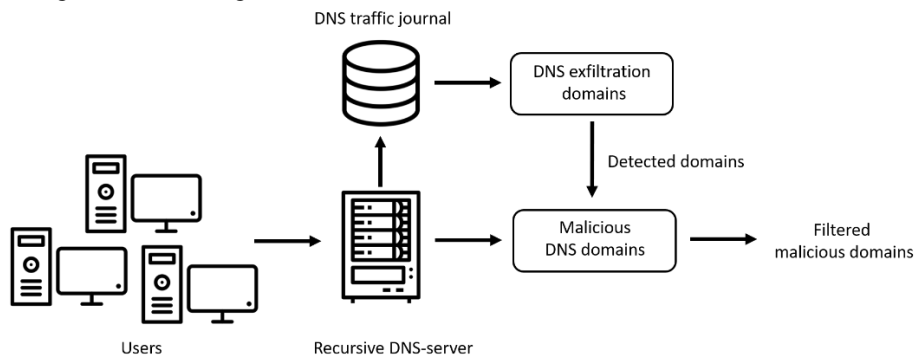


Fig. 1. Malicious DNS traffic detection scheme

3.1 Usage of the Isolation Forest Algorithm for the Attacks Detection

The Isolation Forest algorithm allows to detect the anomalies by the recursively generating partitions on a data sample by randomly selecting an attribute and then randomly selecting a split value for an attribute between the minimum and maximum values allowed for that attribute. To detect the anomaly, the data represented by the tree structure, named isolated tree, is recursively distributed. Then the number of sections required to isolate the point is interpreted as the length of the path within the tree to reach the terminating node, starting from the root [20].

The main advantages of the isolation forest algorithm are a low linear time complexity and a small memory requirement. It is able to deal with high dimensional data with irrelevant attributes, and is able to perform the training with or without anomalies in the training set. In addition, algorithm is able to provide detection results with different levels of granularity without the retraining procedure [21].

Let us assume $Q = \{q_1, \dots, q_n\}$ as a set of d -dimensional points, where each point is a feature vector, that describes malicious DNS traffic.

In order to detect the malicious requests, it is necessary to construct data structures with such properties: for each node T in a tree, where T is either an external node without a child, or an internal node, or exactly with two child nodes (T_l, T_r); node T consists of an attribute q and a value for splitting p such that $q < p$ determines the transition of the data point to T_l or T_r .

The resulting set of feature vectors of malicious DNS traffic, represented by the points, is recursively divides Q by randomly selection of the attribute q and division of the value p until any node has only one instance or all data in the node has no equal values. Then, in the constructed tree, each point in Q is isolated at one of the external nodes. Anomalous points (malicious traffic detected) are those characterized by a shorter path length on a tree, where the path length $h(q_i)$ of the point $q_i \in Q$ is defined as the number of edges q_i extending from the root node to reach the external node.

In order to evaluate the anomaly score of the analyzed data the observation that the isolated tree structure is equivalent to the structure of a binary search tree (BST) is taken into account. Thus, the estimation of the average value $h(q)$ for the external nodes is the same as for the unsuccessful BST search:

$$c(m) = \begin{cases} 2H(m-1) - \frac{2(m-1)}{n}, & \text{for } m > 2, \\ 1, & \text{for } m = 2, \\ 0, & \text{otherwise} \end{cases} \quad (1)$$

where n - the testing data size;

m - the size of the sample set and H is the harmonic number, which can be estimated by $H(i) = \ln(i) + \gamma$, where γ is the Euler-Mascheroni constant;

$c(m)$ represents the average of $h(q)$ given m .

In order to normalize the value of $h(q)$ and to perform the anomaly score evaluation for a given sample q we can use equation:

$$s(q, m) = 2^{-\frac{h(q)}{c(m)}}, \quad (2)$$

where $E(h(\varphi))$ is the average value of $h(\varphi)$ from the set of generated isolated trees.

It worth mentioning, that note that for any given traffic sample φ :

$$s = \begin{cases} \text{is close to 1 then } \varphi \text{ is very likely to be an anomaly,} \\ \text{is smaller than 0.5 then } \varphi \text{ is likely to be a normal value,} \\ \text{is around 0.5, the sample doesn't have any anomaly.} \end{cases}$$

3.2 Data Gathering

At this stage the data gathering is performed. DNS-traffic is to be gathered and saved as DNS-logs files. Each DNS-log file describes DNS-traffic during the specified time window α . Each i -th DNS-log string can be presented as the tuple:

$$R_{t_i} = \langle t, MAC, d, A, Qr \rangle, \quad (3)$$

де t – time-stamp;

MAC – MAC-address of infected host;

d – the full queried domain name;

$A = \{a_j\}_{j=1}^{N_A}$ – the set of the resources records in the answer section of the DNS-respond, N_A – the number of the resources records; for example, a set of the A-records values (or an empty string in the situation of the NXDOMAIN answer, when the requested domain name does not exist);

Qr – query type, for example A, NS, PTR etc.

Presented in a such way DNS-logs strings are to be grouped by the primary domain name:

$$\left\{ R_{t_i} \mid \langle d_{prim} \rangle_{R_{t_i}} = \langle d_{prim} \rangle_{R_{t_i+\Delta}} \right\} \xrightarrow{func_g} (R_{t_i} \cup R_{t_i+\Delta}) \in R_d, \Delta \in (0; n\alpha], \quad (4)$$

where d_{prim} – the primary domain for some domain name;

$func_g$ – a group function for the DNS-logs strings concerning the primary domain name and time for data gathering;

R_d – a set of the DNS-logs strings for each domain name, grouped by the primary domain name;

n – a number of the data samples which are to be classified.

3.3 Features Exfiltration

The feature extraction is performed during the time window α :

$$R_d \xrightarrow{func_e} \varphi, \quad (5)$$

where $func_e$ – a feature extraction function.

Feature vector φ can be presented as follow:

$$\varphi = \{f_i\}_{i=1}^{Nf}, \quad (6)$$

where $\varphi \in \Omega$, $\Omega = \{\varphi_i\}_{i=1}^{N_\varphi}$ – set of feature vectors;

N_φ – a total number of feature vectors;

N_f – a total number of features;

f_1 – the domain name length;

f_2 – the number of the unique symbols in the domain name;

f_3 – the longest meaningful word length over domain name length average;

f_4 – the value of the domain name's entropy;

f_5 – TTL-periods (mode);

f_6 – TTL-periods (median);

f_7 – TTL-periods (average value);

f_8 – the number of A-records in the incoming DNS-message;

f_9 – the number of IP-addresses of the domain name;

f_{10} – the value of an average distance between the IP-addresses of the domain name;

f_{11} – a value of the average distance between the IP-addresses in the domain name (concerning to A-records set);

f_{12} – a number of the unique IP-addresses in the domain name (concerning to A-records sets);

f_{13} – a value of average distance between the unique IP-addresses in the domain name (concerning to A-record sets);

f_{14} – a number of domain names which share the same IP-address;

f_{15} – the sign of the usage of the infrequent DNS records types, 0 – if there is such usage, 1 – otherwise;

f_{16} – a value of the DNS-records entropy, which is evaluated as a discrete random variable X using the formula: $H(X) = - \sum_{i=0}^n \Pr(xi) * \log \Pr (xi)$;

f_{17} – a maximum DNS-messages' size concerning to the domain name; f_{18} – an average DNS-messages' size concerning the domain name;

f_{19} – usage of dynamic DNS (DDNS);

f_{20} – an unique query ratio;

f_{21} – an unique query volume;

f_{22} – a resource records type distribution;

f_{23} – a DNS-query succeed sign.

3.4 DNS based Attacks Detection Procedure

The DNS data exchange detection stage is performed using the anomaly detection classifier – isolation forest [20, 21]. The aim of classifier is to assign each obtained feature vector to malicious or benign class.

Isolation forest algorithm is classic classifier without the teacher. It learns using only existing legal data and is able to detect the anomalous behavior.

Let us consider the training and testing phase of the algorithms.

The training phase uses the set of constructed feature vectors and outputs the set of anomaly scores s for each feature vector.

The input data for the classification algorithm is the set R_d for each domain name D and for a period of time t , and the result is an anomaly score rated from 0 to 1.

The output of the learning phase is the set of anomaly thresholds T_s corresponding to each analyzed feature vector that are to be applied to the new data.

The testing phase deals with the obtaining of new samples, where they are to be processed by the algorithm in order to estimate the sample's score s using the *iforest* function, as follows:

$$Q \xrightarrow{\textit{iforest}} s, \quad (7)$$

where *iforest* – the classification function for the gathered data.

If the obtained value exceeds the anomaly score ($s > T_s$), the sample is considered anomalous and the domain referenced will be considered as the malicious domain and is to be blocked.

3.5 Blocking of the malicious DNS traffic

Domain names that are to be classified can be assigned into two categories: malicious and legitimate.

As soon as these domain names are identified as malicious the security scenario for the attack's mitigation is to be applied in order to block the malicious queries in the network.

4 Experiments

For the purpose of technique efficiency evaluation, a number of experiments were held. An aim of the experiments was to estimate the ability of the method to detect malicious DNS queries. To train the system, the dataset [22] was used. It presented the benign (users') DNS traffic. To test the system, a set of DNS-traffic tools were used to generate malicious traffic:

1. DNScat-P (a generator of A type queries) [23];
2. DNScapy (Scapy packets generator, using SSH tunneling, including Socks proxy) [24];
3. TUNS (generator for CNAME records) [25];
4. PSUDP (exfiltration tool for DNS queries) [26];
5. dns2tcp (query generator of the KEY and TXT types) [27];
6. tcp-over-dns (queries generator with the support of LZMA, as well with TCP and UDP traffic tunneling [28];
7. iodine (a DNS tunneling program. It uses a TUN or TAP interface on the endpoint) [29].

For the purpose of the C&C server's imitation the set of "fake" domain names was registered. The C&C servers made it possible to simulate malicious activity (such actions as command and control traffic transfer using DNS-tunneling, cycling of IP-mapping, domain name changing, cyclically changing of DNS A-records and NS-records for the same domains using round robin algorithm, etc.).

In addition to implement proposed technique the framework BotGRABBER was employed [30-33]. It is a multi-vector protection system capable to analyze network and host activity, as well as to implement the needed security scenario of the network reconfiguration according to the type of cyberattack performed by the intruders.

Experimental studies for each type of attack were conducted within 24 hours.

During each experiment, the above tools generated more than 580,000 external DNS queries. In addition, a network activity of 1,000 users was emulated.

The test result of the isolating an anomalous feature vector, presented as a point in a Gaussian distribution, is given in fig.2.

The experimental results were estimated via standard sensitivity (SN), specificity (SP), and detection efficiency (Q) performance measures, taking into account the quantity measures of True Positives (TP), True Negatives (TN), False Positives (FP), False Negatives (FN):

$$SN = TP / (TP + FN), SP = TN / (TN + FP), Q = (TP + TN) / (TP + TN + FP + FN). \quad (8)$$

The experimental results, presented in table 1, showed that the effectiveness of the malware detection is in the range from 94,57 to 99,54%, while the false positives rate not exceeded 4,2%.

Possible security scenario is to be applied in the situation of DNS tunneling attack may be as following [34]:

1. Disallowing internal DNS servers to resolve to external addresses and do the external resolution only through a proxy should prevent this technique.
2. In the case of captive portals, resolving external addresses only after sign-up may work. But then again, there are also other ways for getting around the captive portal, e.g. capturing and then assuming an already signed-up MAC address (which requires much less preparation).
3. Blocking certain domains/IP blocks/regions is surely always possible, but ineffective if the other end could potentially be anywhere.

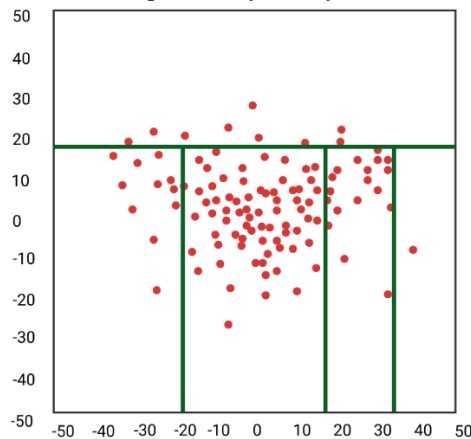


Fig. 2. The isolating an anomalous feature vector, presented as a point in a Gaussian distribution

Figure 3 shows a timeline of the DNS traffic from the malicious activity: before attack and after the detection and the security scenario appliance.

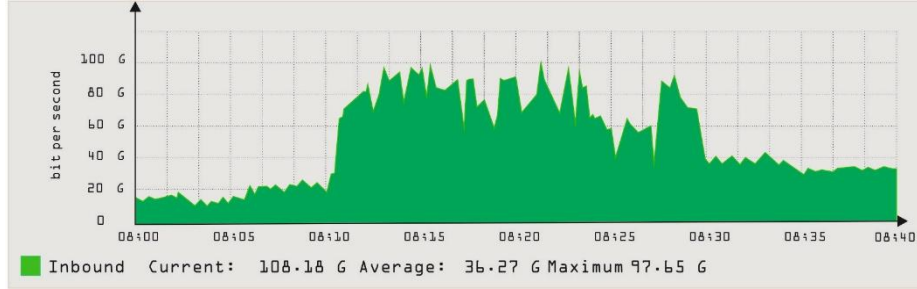


Fig. 3. A timeline of the DNS traffic from the malicious activity: before attack and after the detection and the security scenario appliance

Table 1. Test result of malicious DNS traffic detection: sensitivity, specificity, detection efficiency, true positives (TP), true negatives (TN), false positives (FP), false negatives (FN)

DNS attack tool	Data set				Results		
	malicious DNS-traffic		Benign DNS-traffic		Sensitivity, %	Specificity, %	Detection efficiency, %
	TP	FN	TN	FP			
DNScat-P	97065	169	56008	544	99,83	99,04	99,54
DNScapy	88755	2443	56444	432	97,32	99,24	98,06
TUNS	76001	765	56998	219	99,00	99,62	99,27
PSUDP	80210	877	32100	3347	98,92	90,56	96,38
dns2tcp	84007	1998	87332	529	97,68	99,40	98,55
tcp-over-dns	78059	6990	55309	665	91,78	98,81	94,57
iodine	80665	1121	60487	199	98,63	99,67	99,07

5 Conclusion

The paper presents the new technique for cyberattacks detection based on DNS traffic analysis. It enables the proactive malicious requests detecting in corporate area networks based on DNS protocol, and is aimed to identify and block the malicious domains and DNS data deletion requested by the attackers.

The process of malicious requests detection is based on the use of "isolation forest" algorithm, which allows to detect the anomalies in DNS data exchange.

The anomaly in the DNS traffic is detected due to analysis of the set of features concerning the requests and responses that may indicate the attack presence in the network.

The experimental results showed that the detection effectiveness of the cyberattacks that use the DNS traffic is in the range from 94,57 to 99,54%, while the false positives rate not exceeded 4,2%.

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Improved Secure Stream Cipher for Cloud Computing

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Abstract. Today cloud services have revolutionized the way we store and share different data. At the same time, most of the data are unsecured and vulnerable to various cyberattacks. In this paper cloud services concept and mechanisms of their work were considered. The cryptographic encryption algorithms used in cloud services were analyzed as well as comparative analysis of most popular up-to-date cloud services Wuala, DropBox and Google Drive was carried out. As the result of analysis, the advantages and the weakest places of each cloud services were defined. Besides that, in this work Google Drive work scheme and data protection in the cloud service were presented. The main disadvantage of cipher RC4-128, which is used in this cloud service, is identified. After this improved stream cipher based on RC4-128 has been developed. It contains additional byte transformations in the PRN formation algorithm, an additional PRN and a new incoming message encryption algorithm using the generated threads. As a result, these solutions provide the cryptographic security of the proposed stream cipher. Experimental study of improved stream cipher for cloud services was carried out. It was focused on data encryption speed research and statistical testing using the standardized NIST STS technique.

Keywords: cloud computing, cloud services, cloud security, cybersecurity, cryptography, stream cipher, algorithm, encryption, PRNG, RC4, NIST STS.

Introduction

In contemporary information and communication technology (ICT) world, cloud-based environments have been in active use for a long time: both on the Internet and across businesses. The potential for freely scalable technology allows not only to use direct-purpose information products, but also extending the administration and

maintenance of user-generated data, their processing and own funds usage in the field of cloud technologies [1].

Cloud technology topic is becoming wider. Contemporary scientific and practical conferences are devoted to further development and ways of building new infrastructure of the state, new technological solutions for ICT implementation. Cloud technologies are the basic infrastructure of the third generation, which allows to create powerful ICT with a new architecture and capabilities. According to the forecasts of the leading IT consulting companies in the world, the rapid improvement and spread of cloud computing will completely change the IT industry development in the coming years and will have a significant impact on other important spheres of human life.

The essence of “cloud” technologies [2] is to provide end users with remote dynamic access to computing resources, services and applications (including information and operating systems, server software, etc.) over the Internet or through a corporate network (Fig. 1 [3]). The tendency of hosting sphere development and necessity for people to use public resources was defined by the emergent need for new software and information digital services which could be managed from the inside but which would be more economical and efficient.

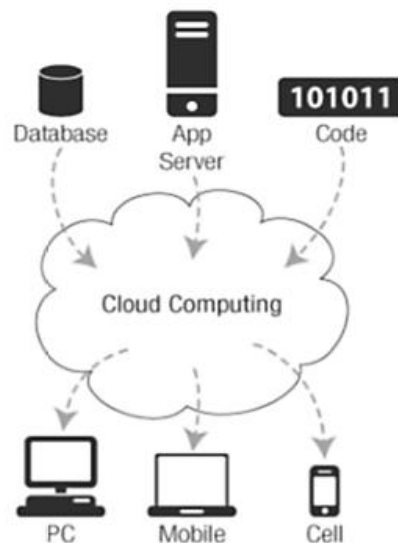


Fig. 1. Cloud computing scheme and concept

Using “cloud” technologies can not only reduce the cost of physical equipment, but also massively combine data with their subsequent protection, ability to work remotely with the enterprise information system and personalize “cloud” core for the needs of the company. But “cloud” technologies have several disadvantages. The main one is the threat to information security [4]. According to standards, described in work [1], *cloud security* means protecting information and information systems from unauthorized access, use, disclosure, disruption, modification, or destruction in order to

provide integrity, confidentiality and availability in cloud services. In a highly competitive environment, companies are most afraid of: data leaks from the “cloud” provider network due to data interception, loss of control over data and applications, inability to destroy data, insider action by the provider or other “cloud” users. For protection it can be used data encryption or depersonalization. And not only the data stored with the provider, but also the channel of communication with it should be encrypted. Therefore, the development of really persistent data encryption algorithms as well as improving existing information security methods in cloud services are very relevant in our time and still actual in future during 5G-6G implementing.

The main purpose of the study is to provide cryptographic security in cloud services without reducing performance by improving stream cipher.

Up-to-date Cloud Services Review

Cloud services are the latest type of networking services that enable virtual media information to extend the hardware and software resources of a user's computer device. The cloud services emergence has become possible during development process of cloud computing technologies, which are implemented under the conditions of dynamic large-scale access to distributed external network resources. Providing such access as a separate service remains a type of cloud service [1-3].

Cloud services are usually provided on the Internet using modern Internet browsers. Cloud services utilize virtual machines that operate in large datacenters and replace physical personal computers and servers. The main difference from the usual use of software in cloud services is that the user can combine the internal resources of his computer device and the software resources provided to him as an online service. During this user has full access to managing his own data, but cannot control the operating system or software base through which this work is done.

2.1 DropBox Storage Service [5]

Login and registration. For registration and login, it is used secure communication channel (TLS). Registration can be done on the website or during client installation. During registration on the website the user has to enter his first and last name (arbitrary lines), email address and password. One email address can only be associated with one account. During registration, a minimum password length of at least six characters is imposed; a maximum limit is not set. In addition, no email address should be used as a password. During registration on the website DropBox provides a hint of the password quality, but accepts weak passwords. The registration process during client installation is slightly different: the client application does not have a password strength indicator and the user has to repeat the password. When entering a previously used address, a corresponding message is displayed. When first logged in through a client app, the user enters an email address and password. After passing the authentication, the security token is transmitted to the server and stored on the client side for further user authentication. DropBox does not send an activation message to

the email immediately after registration, it only happens after trying to get the first URL to share the file, so the user can use the new account as soon as fill in the registration form. In case of a failed login attempt, DropBox informs the user that one element of the login / password pair is incorrect but does not specify which one.

If a user has lost his password, Dropbox sends a message to the user's registered email. This email contains the URL of a secure web page for entering a new password. Dropbox prevents password hijacking by temporarily blocking your account after many unsuccessful attempts to sign in for a specified period of time. Dropbox has the ability to use two-factor authentication. This option can be enabled in profile settings. In can be used one-time access codes that can be received on a mobile phone. It is also possible to use barcodes using Time Based One Time Password mobile applications.

Secure communication channel (SCC). During the DropBox analysis, the principle of securing communication channel between the client and the server was considered.

SCC formation protocol – TLS.

Message authentication algorithm – AES_256_CBC (SHA1).

Key agreement algorithm – ECDHE_RSA (2048 bit).

Data storage security. DropBox uses AES-256 to encrypt data stored on servers. This data will not be encrypted on the client side, instead DropBox encrypts the data after booting on the server side using its own encryption key. Since DropBox encrypts data on the server, user can not be sure in data privacy.

Data encryption algorithm –AES-256.

Data encryption key possession – the key is owned by the provider.

2.2 Google Drive Storage Service [5,6]

Login and registration. A SCC is used to register and log in. New accounts can be created on a Google page. To use the service must have a Google account, which is the same for all services and email address tied to Gmail. During registration, the user must be sure to provide first and last name, gender, birth date, come up with a unique email address and enter password twice. Also need to enter information from the image. One email address can be associated with one account. To create a Google Account, you must select a password, which include at least 8 characters, but not more than 100 characters. In passwords can be used Latin letters (both large and small: A-Z, a-z), numbers (0-9) and punctuation marks. The password can consist of only one character's group. When creating a password, the system provides a password quality hint. Google also rejects common passwords. Thus, weak passwords are not accepted. Since the login is unique to all Google applications – no additional signup confirmation is required. If unsuccessful attempt to log in, Google notifies the user that one element of the pair login / password is not correct, but does not specify what kind of. If a user forgets his password, he gets two possible ways to set a new password:

- a secure page for resetting user's password, URL sent by mail;
- using a code that is sent to a mobile phone via a short message or can be communicated during a phone call.

Google prevents brute force passwords using mandatory requirements Input characters from the image after a series of failed login attempts in service. Google has the ability to use two-factor authentication, this option can be enabled in the profile settings. It is used one-time access codes that can be send on mobile phone.

SCC. During the analysis of Google Drive, the security principle for communication channel between client and server was considered.

SCC formation protocol – TLS.

Message authentication algorithm – RC4_128 (SHA1).

Key agreement algorithm – ECDHE_ECDSA (256 bit).

Data storage security. Google Drive does not use server-side data encryption.

2.3 Wuala Storage Service [7]

Login and registration. A SCC is used to register and log in. New accounts can only be created using the Wuala App. During registration a user must provide a unique name, email address and password. A single email address can be associated with multiple accounts. Only minimum lengths of at least six characters are imposed on the password, no maximum limit is set. Wuala provides hint about password quality during registration, but does not reject weak passwords. Wuala does not send an activation message to the email to confirm the fact of registration. In case of unsuccessful login attempt, Wuala informs the user that one or both of the elements of the login / password pair is incorrect but does not specify which one. Passwords are not stored on Wuala servers, so the ability to recover a lost password is not available.

Wuala provides optional password hint functionality. The password hint can be used for a single username or email address and will be sent to a registered email address. If there are multiple accounts registered with the same email address – multiple emails will be sent, one for each account that has a password hint. The password hint feature allows to collect information about already registered usernames and email addresses. There are no restrictions on the number of failed login attempts. Two-factor authentication is not currently implemented in Wuala.

SCC. The Wuala SCC uses its own client-server communication protocol rather than standardized and well-known SSL / TLS. According to Wuala press releases, integrity checks are being used to protect data during transmission, but no detailed documentation on mechanisms and protocols has been published. In conjunction with the convergent encryption schemes used by Wuala, the lack of encryption during transmission allows attackers to receive messages being transmitted and to attempt information-gathering attacks.

SCC formation protocol is absent.

Message authentication algorithm – AES_256 (SHA1)

Key agreement algorithm – DHE_RSA (2048 bit)

Data storage security. The idea behind Wuala encryption is to have an unreliable file system whose security is ensured by cryptographic methods. Used scheme is an implementation of directory tree structure for cryptographic file system called Cryptree.

Trust is based on a symmetrical root key that is obtained from a user's password. Wuala calculates the individual keys for each directory and the individual keys for

each file. They all are output through the root key. They can be provided to partners for the purpose of data exchange. Wuala uses converged encryption schemes. This means that key to encrypt the file is derived from its hash value.

The most *important properties of convergent encryption schemes* are:

- 1) Identical plaintexts are encrypted into identical crypto texts, regardless of user;
- 2) Server cannot decrypt the crypto texts without having a copy of the plaintext.

The first property ensures the implementation of encrypted data deduplication feature. The second property protects documents that are unique to the user, such as self-written works, unpublished technical reports, etc.

Converting encryption schemes, on the other hand, have important disadvantages, including the attacks possibility if the attacker has access to the server side. According to press releases, it is noted that Wuala uses AES-256 to encrypt metadata and stored information. The client signs each file with a pair of user keys, in order to identify files that were received from third parties. The signatures are created and verified using RSA-2048, while SHA-256 hash function is used to verify the integrity.

Data encryption algorithm – converged encryption scheme.

Data encryption key possession – the key is stored on the client side.

Table 1 presents what advantages and disadvantages of each studied cloud services [5-7]. So, unlike Wuala's service, Google Drive and DropBox have two-factor authentication, password-attack protection, password recovery mechanism and transfer data by TLS 1.1 protocol (SCC formation protocol).

Table 1. Comparative analysis of modern cloud services

Cloud service	Protection against brute force attacks	Two-factor authentication	Pass recovery mechanism	SCC formation protocol	Message authentication algorithm	Key agreement algorithm	Data encryption algorithm
DropBox	Temporary lock	Password and OTP	Present	TLS 1.1	AES_256_CBC (SHA1)	ECDHE_RSA (2048 bit)	AES-256
Google Drive	Using characters from the image	Password and OTP	Present	TLS 1.1	RC4_128 (SHA1)	ECDHE_ECDSA (256 bit)	-
Wuala	Absent	Absent	Absent	Absent	AES_256 (SHA1)	DHE_RSA (2048 bit)	Converged encryption scheme

One of the major drawbacks of each service is that message authentication uses the SHA1 algorithm, which is considered as outdated and not resistant to hacking. In Google Drive for messages authentication along with the SHA1 algorithm uses an algorithm RC4 that is also a disadvantage of service because it was proven that the modern attacks on the RC4 allow to break it for a few days or even hours. Another drawback of Google Drive is that it does not implement server-side data encryption. Wuala uses the Diffie-Hellman protocol for key agreement, while Google Drive and DropBox use the Diffie-Hellman protocol on elliptic curves.

Table 2 shows the analysis of the basic encryption algorithms used in cloud services. This also was given from previous review part [5-7].

Table 2. Analysis of cryptographic algorithms used in cloud services

Encryption algorithm	Cloud services	Type	Advantages	Disadvantages
AES	DropBox, Wuala	Block cipher	Provides high practical security, effective for implementation on 32-bit platforms, has a number of hardware accelerators	Known theoretical attacks with complexity less than a complete search; can not fully use the capabilities of 64-bit platforms; relative obsolescence
RC4	Google Drive	Stream cipher	High speed, variable key size	Vulnerable when using non-random or related keys, one key stream is used twice.
SHA1	DropBox, Wuala, Google Drive	Block cipher	Fast enough, easy to implement	Does not guarantee sufficient protection against attacks

Next Section of the paper consists on improvement of cryptographic security of Google Drive that is most effective among analyzed cloud services; it based on stream cipher but has some vulnerability (Table 2).

This is very important issue because possible types of security challenges for cloud computing services include compromises to the confidentiality and integrity of data in transit to and from a cloud provider and at rest [1,8].

Improving Stream Cipher for Cloud Services

3.1 RC4 Stream Cipher Description

Google Drive is data store owned by Google Inc. that allows users to store their data on servers in the cloud and share it with other users on the Internet.

During the analysis of Google Drive, the principle of securing communication channel between the client and the server was considered in Section 2. Let's take a closer look at the RC4-128 message encryption algorithm [9]. RC4 is streaming cipher developed by Ron Rivest in 1987, when he worked for the US company RSA Security. Has become a common algorithm used in such popular protocols as TLS (to secure internet traffic) and WEP (for wireless network security). Among others, it stands out for its speed and ease of software implementation, but the PC4 has flaws that indicate its inappropriate use in the latest systems. RC4-128 uses a sequence of numbers from 0 to 127 in the array S , which changes when algorithm works (Fig. 2).

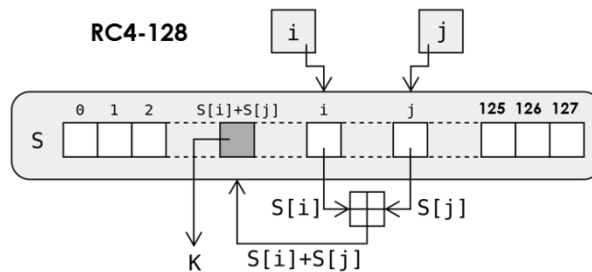


Fig. 2. Scheme of RC4-128 stream cipher realization

RC4-128 consists of following processes: Key Scheduling Algorithm (KSA), Pseudo-random Number Generation (PRNG) and Data Encryption. These processes are described by Pseudo-code 1. Besides that, RC4 is value part of security system in BitTorrent, Skype, Opera, Kerberos, PDF etc.

Pseudo-code 1:

1. .KSA to set the initial value of the array S :
 - 1.1. KSA starts work with S initialization such as $S[i]=i$, for $i = \overline{0,127}$.
 - 1.2. The secret key is given by a set of numbers, which are placed in a key array K , that also contains 128 elements. Usually, a short sequence of numbers is selected, which is then repeated until K is filled.
 - 1.3. The key array is used to convert S by the following scheme:
 - 1.3.1. $j=0$;
 - 1.3.2. For $i = \overline{0,127}$ the following steps are performed:
 - 1.3.2.1. $j=(j+ S[i] + K[i])\text{mod}128$;
 - 1.3.2.2. $buf=S[i]; S[i]=S[j]; S[j]= buf$.
2. PRNG algorithm for encryption:
 - 2.1. A byte array k of PRN is generated, selecting random elements of the S array for the next sample:
 - 2.1.1. $i = 0; j = 0$;
 - 2.1.2. The following algorithm is used to generate each byte of a random stream:
 - 2.1.2.1. $i = (i+1)\text{mod}128$;
 - 2.1.2.2. $j = (j+S[i])\text{mod}128$;
 - 2.1.2.3. $buf=S[i]; S[i]=S[j]; S[j]= buf$.
 - 2.1.2.4. $t = (S[i] + S[j])\text{mod}128$;
 - 2.1.2.5. $k = S[t]$
3. Data Encryption:
 - 3.1. X -plain text; Y -ciphertext; $Y_i = X_i \oplus k$.

The Fast Software Encryption Cryptographic Conference took place in Singapore in 2013, the main event being the speech of American Professor Dan Bernstein, who introduced the method of bypassing TLS (Transport Layer Security) and SSL (Secure Sockets Layer) protocols if they use RC4 encryption algorithm [10].

Successful attack on the cipher can be carried out due to insufficient randomness of the bit stream to which the message is transmitted. If chase a large number of network packets through this stream, it can be detected enough repetitive patterns to get the original content of the message. Successful attacks require the capture of large amounts of encrypted traffic. The researcher reported that he managed to bypass TLS protection in 32 hours, but hackers can apply various techniques to optimize and accelerate the RC4 hacking process. Apparently, this encryption algorithm is not crypto resistant (secure) and requires improvement [11].

3.2 Proposed Improving of RC4 Stream Cipher

Therefore, improved stream cipher called ISC2k19 was developed, which eliminates the disadvantages of RC4 by changing the PRNG algorithm to substitution table implementation (S-box) and the use of constants, generation of additional PRNG flow and data encryption algorithm changing, which allows to increase the cryptographic security [12] of the algorithm.

ISC2k19 uses a sequence of numbers from 0 to 255 in the array S , which changes during algorithm works. ISC2k19 consists of four following processes (described by Pseudo-code 2):

Pseudo-code 2:

1. KSA to set the initial value of the array S :
 - 1.1. KSA starts work with S initialization such as $S[i]=i$, for $i = \overline{0,127}$.
 - 1.2. The secret key is given by a set of numbers that are placed in the key array K , which also contains 128 elements. Usually, a short sequence of numbers is selected, which is then repeated until K is filled.
 - 1.3. The key array is used to convert S by the following scheme:
 - 1.3.1. $j=0$;
 - 1.3.2. For $i = \overline{0,127}$ the following steps are performed:
 - 1.3.2.1. $j=(j+ S[i] + K[i])\text{mod}128$;
 - 1.3.2.2. Then $S[i]$ and $S[j]$ are modified using a tables of substitutions (S-box, Table 3) and constants (Const, Table 4);
 - 1.3.2.3. $S[j]= Sbox (S[j]+Const[i])$; $S[i]= Sbox(S[i])$.
 - 1.3.2.4. $buf=S[i]$; $S[i]= S[j]$; $S[j]= buf$.
2. PRNG algorithm for randomly selecting array elements and changing array S , for $S[i]$, where $i = \overline{0,127}$.
 - 2.1. A byte array of PRN is generated by selecting random elements of array S for the next sample:
 - 2.1.1. $i = 0$; $j = 0$;
 - 2.1.2. The following algorithm is used to generate each byte of a random stream:
 - 2.1.2.1. $i = (i+1)\text{mod}128$;
 - 2.1.2.2. $j = (j+S[i])\text{mod}128$;
 - 2.1.2.3. Then $S[i]$ and $S[j]$ are modified using a tables of substitutions (S-box, Table 3) and constants (Const, Table 4);
 - 2.1.2.4. $S[j]= Sbox (S[j]+Const[i])$; $S[i]= Sbox(S[i])$
 - 2.1.2.5. $buf=S[i]$; $S[i]=S[j]$; $S[j]= buf$.
 - 2.1.2.6. $t = (S[i] + S[j])\text{mod}128$;
 - 2.1.2.7. $k = S[t]$.
3. The algorithm for generating an additional stream of PRN for randomly selecting array elements and changing array S , $S[i]$, where $i = \overline{128,255}$.

3.1. Bytes r of PRN of key are generated by selecting random array S elements.

3.1.1. $i = 128, j = 0$.

3.1.2. $j = (j+1) \bmod 128$.

3.1.3. $S[m] = S[i-1] \oplus (S[i-1] \lll j)$.

3.1.4. $r = S[m]$.

4. Data encryption:

$$4.1. X - \text{plain text}; Y - \text{ciphertext}; Y_i = \begin{cases} X_i \oplus k, & i \bmod 2 = 0; \\ X_i \lll r, & i \bmod 2 = 1. \end{cases}$$

Both Table 3 and Table 4 are used in PRNG algorithm forming process of ISC2k19 stream cipher for security improving.

Table 3. Substitutions table (S-box) of ISC2k19 stream cipher

\	0	1	2	3	4	5	6	7	8	9	a	b	c	d	e	f
0	63	7c	77	7b	f2	6b	6f	c5	30	01	67	2b	fe	d7	ab	76
1	ca	82	c9	7d	fa	59	47	f0	ad	d4	a2	af	9c	a4	72	c0
2	b7	fd	93	26	36	3f	f7	cc	34	a5	e5	f1	71	d8	31	15
3	04	c7	23	c3	18	96	05	9a	07	12	80	e2	eb	27	b2	75
4	09	83	2c	1a	1b	6e	5a	a0	52	3b	d6	b3	29	e3	2f	84
5	53	d1	00	ed	20	fc	b1	5b	6a	cb	be	39	4a	4c	58	cf
6	d0	ef	aa	fb	43	4d	33	85	45	f9	02	7f	50	3c	9f	a8
7	51	a3	40	8f	92	9d	38	f5	bc	b6	da	21	10	ff	f3	d2
8	cd	0c	13	ec	5f	97	44	17	c4	a7	7e	3d	64	5d	19	73
9	60	81	4f	dc	22	2a	90	88	46	ee	b8	14	de	5e	0b	db
a	e0	32	3a	0a	49	06	24	5c	c2	d3	ac	62	91	95	e4	79
b	e7	c8	37	6d	8d	d5	4e	a9	6c	56	f4	ea	65	7a	ae	08
c	ba	78	25	2e	1c	a6	b4	c6	e8	dd	74	1f	4b	bd	8b	8a
d	70	3e	b5	66	48	03	f6	0e	61	35	57	b9	86	c1	1d	9e
e	e1	f8	98	11	69	d9	8e	94	9b	1e	87	e9	ce	55	28	df
f	8c	a1	89	0d	bf	e6	42	68	41	99	2d	0f	b0	54	bb	16

Table 4. Table of constants (Const) of ISC2k19 stream cipher

Index	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Constant	8c	a1	89	0d	bf	e6	42	68	41	99	2d	0f	b0	54	bb	16
Index	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
Constant	70	3e	b5	66	48	03	f6	0e	61	35	57	b9	86	c1	1d	9e
Index	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47
Constant	e7	c8	37	6d	8d	d5	4e	a9	6c	56	f4	ea	65	7a	ae	08

Index	48	49	50	51	52	53	54	55	56	57	58	59	60	61	62	63
Constant	60	81	4f	dc	22	2a	90	88	46	ee	b8	14	de	5e	0b	db
Index	64	65	66	67	68	69	70	71	72	73	74	75	76	77	78	79
Constant	09	83	2c	1a	1b	6e	5a	a0	52	3b	d6	b3	29	e3	2f	84
Index	80	81	82	83	84	85	86	87	88	89	90	91	92	93	94	95
Constant	51	a3	40	8f	92	9d	38	f5	bc	b6	da	21	10	ff	f3	d2
Index	96	97	98	99	100	101	102	103	104	105	106	107	108	109	110	111
Constant	53	d1	00	ed	20	fc	b1	5b	6a	cb	be	39	4a	4c	58	cf
Index	112	113	114	115	116	117	118	119	120	121	122	123	124	125	126	127
Constant	04	c7	23	c3	18	96	05	9a	07	12	80	e2	eb	27	b2	75

Next Section of this work contains experimental technique as well as study of RC4 and improved stream cipher (ISC2k19).

Experimental Study of Stream Ciphers

4.1 Experimental Research Technique

An experimental study conducted to confirm or refute the hypothesis. To obtain the maximum result, it is necessary to clearly describe the study methodology. The conclusions of the theory, that would be experimentally studied should include only observable quantities. If it is difficult to predict the result theoretically, it is advisable to use statistical results. These experiments are based on traditional standards of research study in cryptography [13-15] and particularly in stream cipher security analysis [16-18]. To perform each experiment study, it is necessary:

1. Determine the experimental purpose;
2. Set a target task;
3. Select the research object;
4. Identify input and output data;
5. Create a program of experimental work;
6. Determine the methods and techniques of intervention in the research object;
7. Develop techniques for recording the progress and results of the experiment;
8. Prepare instruments, devices, applications, etc.

According to the hypothesis, the qualitative nature of the expected results is pre-determined: this will ensure a quick and correct evaluation of them, instantly alert with unexpected results, and help to avoid false conclusions.

4.2 Experimental Study of Ciphers Speed (Experiment №1)

The purpose of this experiment is study the speed characteristics of RC4 and improved stream cipher ISC2k19. To achieve mentioned purpose the following tasks should be performed:

1. Estimation the speed of 100KB data cryptographic transformation by software application based on both stream ciphers;
2. Estimation the speed of 1MB data cryptographic transformation by software application based on both stream ciphers;
3. Estimation the speed of 10 MB data cryptographic transformation by software application based on both stream ciphers;
4. Estimation the speed of 100 MB data cryptographic transformation by software application based on both stream ciphers.

Research object: the process of data cryptographic transformation.

Input data: encryption file, key stream.

Output data: encryption/decryption speed.

The experiment is performed manually with the help of the developed software application; the results are recorded in the Table 6. To confirm the achievement of this purpose, a comparative speed test of the encryption and decryption was carried out (between software-implemented cipher RC4-128 and developed ISC2K19 cipher). Testing was performed on four different computers; the characteristics of their hardware are given in Table 5.

Table 5. The characteristics and CPUs of the machines being tested

№	Processor
1	Intel Pentium CPU G4400 3.30GHz
2	Intel Pentium CPU G4520 3.6GHz
3	Intel Core CPU i3-6100T 3.2GHz
4	Intel Core CPU i7-5775R 3.3GHz

Testing was carried out for four selected files of different sizes (Table 6).

Table 6. Average speed test results for two studied ciphers

Stream Cipher	Processor			
	1, MB/s	2, MB/s	3, MB/s	4, MB/s
RC4-128	24,1	23,6	22,7	25,8
ISC2K19	20,3	20,2	19,5	20,9

The speed of ISC2K19 algorithm averaged was 20,2 MB/s, while the RC4-128 speed is 24,05 MB/s. Therefore, the improved stream cipher ISC2K19 showed worse results than RC4-128 during speed tests by 14.8%. But since the difference in time between RC4-128 and ISC2K19 data encryption is negligible, the speed of ISC2K19 is not a major disadvantage (security is priority parameter).

4.3 Experimental Study of Ciphers Statistical Security (Experiment №2)

The purpose of this experiment is study the statistical characteristics of cryptographic security of RC4 and improved stream cipher ISC2k19. To achieve mentioned purpose the evaluation the statistical characteristics of both stream ciphers using the NIST STS technique.

Research object: data encryption process.

Input data: encrypted files by size 100 KB, 1MB, 10MB, 100MB.

Output data: test coefficients.

The experiment is performed by a console version of the NIST STS [19]. In accordance to [20-21] the most modern analytical attacks are statistical; during cryptanalysis, a large number of encryptions are performed to obtain a key, and round key variants are formed based on ciphertexts. When processing a sufficiently large sample of ciphertexts formed on a single key, the correct value of key bits is more common than the other variants. Obviously, the probability of finding the right pair, which gives a specific value of the key, depends on the statistical properties of the cipher. To increase the complexity of cryptanalysis, the properties of cryptograms must be close to random sequences. Therefore, a necessary (but not sufficient) condition for cipher security to analytic attacks is to provide good statistical properties of the output sequence (ciphertexts).

To test the statistical characteristics of the developed cryptoalgorithm it was tested in accordance with the NIST STS technique [19]. Software implementation of the algorithm is subjected to statistical testing using the NIST STS. The following parameters were selected for testing:

1. The length of the tested sequence $n=10^6$ bit;
2. The number of tested sequences $m=100$;
3. Significance level $\alpha=0,01$.

Thus, the sample size under test was $N = 100 \times 10^6$ bit; number of tests q for different lengths $q = 188$. Thus, the statistical portrait of the generator contains 18800 values of P probability.

In the ideal case, with specified parameters, only one sequence of one hundred can be discarded during testing, so the pass speed of each test should be 99%. But this restriction is too strict, so a rule based on the rj confidence interval applies. The lower bound in this case is the value $P_{\min} = 0,96015$. From this viewpoint, the results of testing cryptographic algorithm and the key extension algorithm were analyzed.

Table 7. Averaged NIST test results for two studied stream ciphers

Generator	Number of tests, which have been tested more than 99% sequence	Number of tests, which have been tested more than 96% sequence	The number of tests in which values $P>0,01$	The number of tests in which values $P>0,001$
RC4-128	125 (66,49%)	187 (99,46%)	147 (78,19%)	187 (99,46%)
ISC2K19	134 (71,28%)	188 (100%)	161 (85,63%)	188 (100%)

Analyzing the results, it can be concluded that the software implementation of the improved stream cipher passed complex control according to the NIST STS technique and showed better results than RC4-128 on 4.7%.

Conclusions

In the paper up-to-date cloud services Wuala, DropBox and Google Drive was analyzed, this made it possible to understand the schemes of their work, to determine what security methods and algorithms are used for data transmission as well as the main advantages and disadvantages of cloud services were emphasized. Besides, the analysis of cryptographic methods and systems used in cloud services were carried out. This made it possible to understand what are the disadvantages of encryption algorithms and how to get rid of them.

An improved stream cipher ISC2k19 based on RC4-128 (used in TLS, SSL, SSH, WEP, BitTorrent, Skype, Opera, Kerberos, PDF) was developed to provide cryptographic security in cloud services without reducing performance (this improvement is directed on the most effective cloud service Google Drive). This cipher contains additional byte transformations in the algorithm of PRN formation. An additional PRN is also generated.

Experimentally the speed of ISC2k19 realization was compared with RC4-128 and the speed of ISC2K19 showed worse results than RC4-128 during speed tests by 14.8%. But since the difference in time between RC4-128 and ISC2K19 data encryption is negligible, the speed of ISC2K19 is not a major disadvantage. Also was performed an experimental study of security using the NIST STS: ISC2K19 passed complex control by NIST STS and showed better results than RC4-128 on 4.7%.

The future research study can be related with ISC2K19 security analysis and quantitative assessment of its security against various cryptanalytic attacks [22].

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An Android Malware Detection Method Based on CNN Mixed-data Model

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Abstract. The paper proposes an Android malware detection method based on convolutional neural network mixed-data model. This data are presented by API method calls and a set of permissions for the Android app. Word2vec technology was used to represent API calls in a vector space, which creates semantically similar feature vectors for related API calls. To represent a set of permissions, each unique permission is encoded as a binary feature that determines the presence / absence of permission in the input sequence. Obtained sequence is then broken down into nibbles and the code “8421” is applied with further normalization of the result. Both types of vectorized data are the inputs to the convolutional neural network. The architecture of the proposed neural network consists of two separate parallel convolutional branches, each of which processes its own type of data, and the fully connected layers. The structure of both branches is the same, which involves placing in each branch two consecutive layers of convolution, where the first layer maps the simple features that will be used by the second layer to represent higher level behavioral patterns. After the convolution layers, there is a pooling layer placed to reduce the dimension of the data. The outputs from both branches of the network are combined to form the input for fully connected layers, which determine the probabilities of belonging suspicious app to one of the classes – malware or benign.

Keywords: Android malware, API calls, permissions, convolution neural network, word2vec.

1 Introduction

In the last decade, humanity has made a significant leap forward in the development of the information technology industry and, in particular, mobile devices operated by the Android operating system. Mobile features have evolved from just making a phone call to supporting the functionality of a full-fledged computer system. However, the advent of new mobile devices features has automatically created new vulnerabilities for them and has driven an increase in the amount of malware, which are trying to use them. This allows malware to perform a full range of malicious activity,

from accessing and stealing private information to displaying undesirable advertisement and spying of the users' activities. Even today, the Google Play web service is not fully protected against the intrusion of malicious software that becomes available for download to Android users. According to the Kaspersky Lab, over 100 million users downloaded the CamScanner text recognition application in mid-2019, which concealed a Trojan program identified as Trojan-Dropper.AndroidOS.Necro.n [1]. There are different reasons for hackers to commit malicious acts. Most often it is obtaining an award, self-affirmation, entertaining, or as a kind of weapon [2]. Therefore, developing new methods for detecting Android malware remains an important task.

The main purpose of our study is to increase the accuracy of a malware detection process by developing a method that would be based on the involvement of neural networks. As a result of our research a method for detecting malicious Android software based on the use of mixed-data model for convolutional neural network (CNN) have been proposed. Involvement of convolution layers creates an analogy with the human brain, allowing the identification of local features that are subsequently fed to the input of fully connected layers to form a membership degree of an input object to one of the predicted classes. In the field of pattern recognition, such features may be, for example, the presence of inclined lines at a certain angle. Another important advantage is that the weights in the convolution layer are locally connected and move throughout the feature map. This leads to involving much less of a number of weights compared to fully connected neural network architectures.

As an input data for CNN, we used the API method calls and a set of permissions for Android app. Application Program Interface (API) is a set of procedures that represent an intermediate layer for communicating applications between themselves and the Android kernel. In fact, no one high-level action doesn't take place without the participation of API invocation [3]. Thus, by analyzing them, we could represent the behavior of the application through the sequence of API calls. For example, the sequence `getDeviceId ()`, `loadLibrary ()`, `sendTextMessage ()` might be determined as the behavior of receiving and sending information. The detection process may then be defined as a procedure of search the similarity of the program's behavior with the knowledge about the typical malware behaviors.

The process of obtaining program behavior or the sequence of API calls can be done in two ways [4]. The first way is to convert the dex file (bytecode) to Java source code. This approach involves retrieving class files from the incoming dex file, with `dex2jar` utility [5] for example, and further conversion to java code. However, it should be noted that in this approach, decompiled java files do not conform to the original code (a reverse operation to obtain a dex file from received java files is not possible). Therefore, the behavior of an application derived from decompiled files may not match with the actual behavior of the application, and cannot be fully used as a feature for Android malware detection.

In our study another approach was used for representing the behavior of an application, which involves the process of disassembling a dex file with `apktool` utility [6]. This process will produce a set of smali files that are a low-level representation of the Android application. It should be noted that a reverse converting to a dex file is possible, which indicates correlation between both operations.

Except API calls, no less important attributes that can enhance behavior representation is a set of app's permissions. The permissions mechanism restricts access to certain components or functionalities of the application. All permissions used by the application are specified in the `AndroidManifest.xml` file. According to the results of previous studies, the distribution of permissions in malware and benign applications is differed [7, 8]. Thus, knowledge of attracting permissions may indicate a set of potential actions that will need to be granted.

2 Related Works

Considerable attention today is being paid to the problem of Android malware detection. Several solutions have been developed using an academic approach, utilizing features such as permissions, API calls, opcodes, strings, metadata or intents.

In [9], authors had proposed an Android malware detection method based on the method-level correlation relationship of application's abstracted API calls. First, for each Android application's the source code was split into separate function methods and kept the abstracted API calls of them to form a set of abstracted API calls transactions. And then, they calculate the confidence of association rules between the abstracted API calls, which forms behavioral semantics to describe an application. Finally, authors combine machine learning methods to identify the different behavioral patterns of malicious and benign apps to build the detection system.

Another static API-based malware detection system, called MaMaDroid, was introduced in [10]. The MaMaDroid abstracts the API calls performed by an app to their class, package, or family, and builds a model from their sequences obtained from the call graph of an app as Markov chain. The sequences of abstracted API calls for the app, with the transition probabilities used as the feature vector to classify the app as either benign or malware using a machine learning classifier.

Except API calls, permissions can also be used to distinguish behavior between malware and benign Android app. In [11] proposed a permission-based malicious code testing tool called APK Auditor. This offers a user client for granting application analysis requests, an independent database to store application features, and a central server to manage the database and user client. APK Auditor calculates a malware score based on the requestedpermissions and then calculates the malware threshold limit dynamically using logistic regression. Finally, APK Auditor classifies the application as malicious if the calculated application malware score exceeds the malware threshold limit. During a set of experiments on more than 10,000 Android applications, 88% detection accuracy rate was obtained.

In [8] authors propose DroidVecDeep, an Android malware detection method using deep learning technique. During conducting static analyze the authors first extract features such as permissions, actions, sensitive API calls, and use random forests for feature selection. Next they model the extracted features as a document, and then use word2vec to analyze the documents and transform the features into K-dimensional word vectors. And finally the Deep Belief Networks model had been used to establish an optimal detection classifier for Android application classification

However, the main drawback of using only Android permissions as features is a possibility obtain high false positive rate, that is a benign application can mistakenly classified as malicious due to very small difference in permissions sets.

The use of opcodes and residual network as a model for malware detection is presented in [12]. Firstly, the model extracts the opcode sequences using the disassembler. To improve the vector's expressibility of opcodes, Word2Vec strategy was used in the representation of opcodes, and word vector representations of opcodes were also optimized in the process of training iteration. To reduce the redundancy of information, a method of downsampling to organize opcode sequences into opcode matrix was adopted. In order to improve the classification ability of the model, a classifier with more layers and cross-layer connection was proposed to match malicious code in more dimensions based on ResNet.

Another possible direction to detect Android malware is a traffic monitoring. In particular technique for the mobile malware detection based on the malware's network features analysis is proposed in [13]. In the process of monitoring there were collected groups of features, those include the storage resource consumption features, CPU resource consumption features, memory resource consumption features and DNS-based features. As the inference engine for malware detection the support vector machine was used. But despite on the high overall accuracy of technique, it should be noted that not all possible feature vectors, that describe different malware classes, are adequately represented in the training set.

Hybrid technique that involves machine learning is presented in [14]. Authors extract permission, intent, uses-feature, application and API as the static features, and choose the CPU consumption, the battery consumption, the number of running processes and the number of short message as the dynamic features. The raw features were sent to the feature selection module to select some key features and reduce the redundant features based on PCA-RELIEF. Finally, they build a classification model by using SVM and evaluate the unknown Android application by classifying it into malware or benign.

In [15] propose MalDozer, an automatic Android malware detection and family attribution framework that relies on sequences classification using deep learning techniques. Starting from the raw sequence of the app's API method calls, MalDozer automatically extracts and learns the malicious and the benign patterns from the actual samples to detect Android malware. MalDozer can serve as a ubiquitous malware detection system that is not only deployed on servers, but also on mobile and even IoT devices. Malware attribution and detection task is made by using convolution neural network.

3 An Android Malware Detection Method Based on CNN Mixed-Data Model

The proposed method for detecting Android malware based on the use of mixed data for CNN consists of two main steps: creating or training a CNN model and applying or deploying the model to detect Android malware.

The training phase involves the creation of a CNN model on a set of training data and involves three sequential steps: preprocessing, vectorization, and directly CNN training.

Preprocessing stage involves obtaining API calls and a set of permissions. The first data are extracted from multiple smali files while the permissions are extracted from AndroidManifest.xml.

The vectorization process uses word2vec technology to represent API calls in vector space. To vectorize a set of permissions, each unique permission is encoded as a binary feature that determines the presence / absence of permission in the input sequence. The sequence is then broken down into nibbles and the code “8421” is applied with further normalization of the result. Both types of vectorized data are inputs to the convolutional neural network.

Training of the convolutional neural network involves sequentially viewing the entire set of training data presented in vector form and generating for each input object a generalization in the likelihood of its belonging to one of two classes. The neural network architecture consists of two separate parallel branches, each of which processes its own type of data, and the fully connected layers. The structure of both branches is the same, which involves placing in each branch two consecutive layers of convolution, where the first layer maps the simple features that will be used by the second layer to represent higher level behavioral patterns. After the convolution layers, there is a pooling layer placed to reduce the dimension of the data. The outputs from both branches of the network are combined to form the input data for fully connected layers.

The deployment phase involves preprocessing for a suspicious Android application, vectorization of its API calls and permissions, and classification using created a neural network model.

Fig. 1 presents the generalized structure of an Android malware detection method based on CNN mixed-data model. Let us take a closer look at each step of the method.

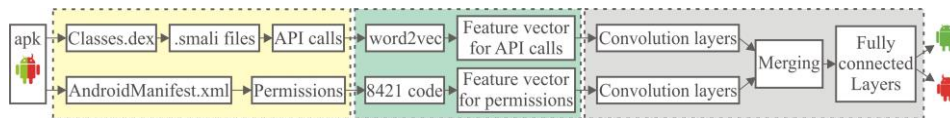


Fig. 1. Generalized structure of an Android malware detection method based on CNN mixed-data model

3.1 Preprocessing

The first step of the proposed method is to extract a list of API calls from smali files and the set of permissions specified in the AndroidManifest.xml file.

Extracting API calls. To get a list of API calls, the dex file is decompiled using the apktool utility. This process will return a set of smali files, containing Android app representation in form of readable Dalvik opcodes. Next stage require parse each smali file and extract the API functions. It should be noted that in the presented method only standard API calls are used, while user methods are ignored. Rejecting custom API calls is explained by the fact that malware can use a large number of third-party methods,

such as some preparatory actions, but standard calls are used to implement the basic functionality (sending a message, checking the network connection, etc.).

The main purpose of getting an API call list is their representation as the behavior of the application. Therefore, in the process of obtaining API calls, it is important to follow their order, which will allow to consider internal relationships between API calls. Because Android applications do not have a single entry point, such as Entry Point in Portable Executable, and applications can be launched not only in the traditional manner by clicking the icon, but in response to intent registered in AndroidManifest.xml, then to collect the behavior of the application, it is important to keep track of all the ways of the application running. To this end, all the services and activities contained in AndroidManifest.xml are added to the list of starting points for collecting application behavior. Next from every starting point, all the API calls that belong to the android, java and javax libraries, that is, calls that interact with the base operating system and defined in the Android specification, are added to the resulting list. If there is a third-party method call, the name of the smali file in which it is implemented is appended to the list of starting points. The algorithm for collecting API calls is shown in fig. 2.

```

Input:  AndroidManifest.xml Manifest
         SetOfSmaliFiles  $S_i$ 
Output: API_list API
begin
  PointsToBeProcessed = emptyList();
  API = emptyList();
  foreach  $M_i$  in Manifest do
    | if  $M_i \in$  AndroidManifest.Activities ||  $M_i \in$  AndroidManifest.Services
    | | PointsToBeProcessed  $\leftarrow$   $M_i$ 
  foreach  $S_i$  in PointsToBeProcessed do
    | foreach Instruction in  $S_i$  do
    | | if Instruction  $\in$  (invoke-* = android, java, javax)
    | | | API  $\leftarrow$  Instruction
    | | if Instruction  $\in$  ReferencesToCustomMethodCall
    | | | PointsToBeProcessed  $\leftarrow$  Instruction
  return API
end

```

Fig. 2. The algorithm for collecting API calls from *smali* files

Extracting permissions. The list of permissions is obtained by simply parsing the AndroidManifest.xml file. The parsing process considers all sections starting with <uses-permission android... />.

3.2 Vectorization of API Calls and Permissions

Vectorization of API calls. As result of parsing process will be obtain the list of API calls for each Android application $A = \{a_1, \dots, a_k\}$. The next step is the vectorization process, that is, the presentation of API calls in the form of real numbers. One way to

achieve this is to encode each API call as a one-hot vector. With this encoding method, the length of the features vector that presents each individual API call, is equal to the dimension of all API calls presented in the dictionary. All number positions are encoded by 0 and the position corresponding to API call is 1. Obviously, with the increasing vector dimension, the amount of the number positions with a zero value increases rapidly. In addition, any two vectors do not correlate in any way among thyself. This situation adversely affects the use of such representation as input for artificial intelligence methods.

In order to obtain a compact vector representation of API calls, the word2vec method [16] was used. This method is used to create embedding predictions in natural language processing systems. Word2vec collects statistics of word co-occurrence in sentences, and then uses neural network methods to solve the task of finding the target word in the context of words (skip-gram model) or finding context in the given word (Continuous Bag of Words – CBoW model). Both models make it possible to maps semantically similar words in close vectors, while distant words in vector space will look different. The classic use of the Word2vec method yields a vector at the output that containing the probability of each word in the dictionary being "in context" for the given word (for the CBoW model). In our study, the word2vec method was used to represent API calls in the form of feature vectors by utilizing the CBoW model. Let's take a closer look at this process.

Suppose an input corpus with size n is specified as $C = \{C_1, \dots, C_n\}$, where every element of which $C_i \in \{M_i \vee B_i\}$ defines the sequence of API calls of a benign application $B_i = \{a_1^b, \dots, a_n^b\}$ or malicious software $M_i = \{a_1^m, \dots, a_n^m\}$. Let every unique API call in corpus C is included in dictionary with size V . Then, represent each API call in form of a one-hot vector such as $r^{a_i} = \{r_1^{a_i}, \dots, r_V^{a_i}\}$, where some $r_l^{a_i} = 1$ and the rest $r_{l'}^{a_i} = 0$, where $l \neq l'$.

Let's denote the context φ for the API call $a_i \in V$ in corpus C as the sequence of API calls that are in the interval $[i-s, \dots, i-1, i+1, \dots, i+s]$, where s – is window size. In this case, the context defines the interval which determines the relationship API call a_i with its s -nearest API calls in training corpus. To generate N dimensional feature vectors, a neural network was used that had comprised of input layer neurons x_1, \dots, x_s , where each value is $x_i = \{x_1, \dots, x_V\}$, one hidden layer h_1, \dots, h_N and the output layer y_1, \dots, y_V .

Then, given the context, the training set for the neural network in the form of a matrix was formed, each element of which is a one-hot vector:

$$M_{training} = \begin{bmatrix} r^{a_{i-s}} & \dots & r^{a_{i-1}} & r^{a_{i+1}} & \dots & r^{a_{i+s}} & r_1^{a_i} \\ r^{a_{i-s}} & \dots & r^{a_{i-1}} & r^{a_{i+1}} & \dots & r^{a_{i+s}} & r_2^{a_i} \\ \vdots & \vdots & \vdots & \vdots & \ddots & \vdots & \vdots \\ r^{a_{i-s}} & \dots & r^{a_{i-1}} & r^{a_{i+1}} & \dots & r^{a_{i+s}} & r_p^{a_i} \end{bmatrix} \quad (1)$$

The vectors $[r^{a_{i-s}}, \dots, r^{a_{i-1}}, r^{a_{i+1}}, \dots, r^{a_{i+s}}]$ are feed to the input layer of the neural network x_1, \dots, x_s that $x_j = r^{a_k}$, where $j = \overline{1, s}$, $k = \overline{i-s, i+s}$. The input layer of the neural network is connected to the hidden layer by a weight matrix W of $V \times N$ dimension, and the hidden layer is combined with the output layer by a matrix W' of size $N \times V$.

With the purpose of obtaining embedding for the target API call by context f at first the output of the hidden layer h (2) was calculated. This involves computation of the average value of the k -rows of the matrix W , which were activated by each group of input neurons x_j (i.e. the average for all ARIs calls that represent context s for a_i).

$$h = \frac{1}{s} W \cdot \left(\sum_{i=1}^s x_j \right) \quad (2)$$

Next the computation of the input for each neuron of the output layer was performed:

$$u_g = v'_{w_g}{}^T \cdot h, \quad (3)$$

where v'_{w_g} is g -th row for output matrix W' .

The last step is to calculate the value of the output layer. The output y_g is obtained by calculating the soft-max function for the input u_g :

$$y_g = p(w_{y_g} | w_1, \dots, w_s) = \frac{\exp(u_g)}{\sum_{g=1}^V u'_g} \quad (4)$$

Next, to obtain the best vector representation for API calls, the weights of the matrices are adjusted W and W' the backpropagation method is used.

Thus, as a result of the word2vec method, we will be considered the weighting matrix W as the feature vector for API calls representation.

Vectorization of permissions. Unlike the incoming list of API calls, in which the order of the API calls sets the context for the API call a_i , significance of information about order of permissions location is not high. So let's consider a way of representing Android permissions which based on the encoding of permission depending on its presence or absence in the input sequence.

Therefore, to represent the set of Android permissions $P = \{\rho_1, \rho_2, \dots, \rho_t\}$, $t \leq U$ in vector form, let's encode them as bit sequence $Z = \{z_1, z_2, \dots, z_U\}$, where U – a dictionary containing all available permissions. Then each bit z_i is set to 1, if for ρ_j permission $j = i$, otherwise 0. The result will be a bit sequence with size U , which consists of zeros and ones responsible for the presence or absence of the corresponding permission in P . Next, we have grouped the bit sequence into nibbles and apply-

ing the 8421 code to each nibble was used. Then the bit sequence have been convert to a encoded bit sequence Z_c with size $D_p = U/4$, in which each value is an integer value from 0 to 15. The resulting encoded bit sequence was defined as a vector representation of the set of permissions. In order to process the obtained feature vector by neural network the normalization of its values to real numbers in the range from 0 to 1 with using min-max normalization was done:

In addition, seven critical permissions, most commonly seen in malware, were selected to distinguish more clearly between malware and benign applications. For the ranking of critical permissions (not to be confused with the category of dangerous permissions defined in the Android specification), the previous studies [17, 18] have been considered and our own research has been conducted. As a result we have selected the most commonly used permissions in Android malware: CHANGE_WIFI_STATE, WRITE_SMS, READ_CONTACTS, ACCESS_NETWORK_STATE, BLUETOOTH, INTERNET and READ_PHONE_STATE.

Each of the selected critical permissions is encoded in one bit and does not form as the result of four-bit encoding. Such manner allows to give more weight for the most critical permissions. Thus, the resulting feature vector for permissions consist of encoded bit sequence and seven more bits, each of which represent one critical permission. The process of obtaining feature vector for an Android app's permission is presented in fig. 3.

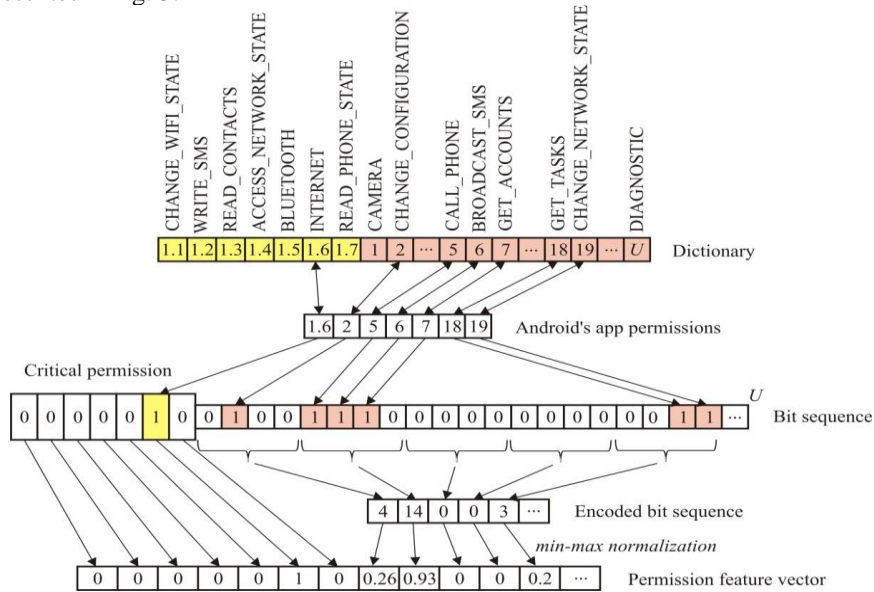


Fig. 3. The process of obtaining feature vector for an Android app's permission

3.3 Convolutional Neural Network

In order to create a model that will produce a conclusion about the suspicious program's behavior, the neural network is trained. The architecture of the proposed con-

volutional neural network, which uses knowledge about API method calls and set of permissions from the Android application to form a conclusion, is presented in Fig. 4.

The proposed neural network consists of two separate parallel convolutional branches, each of which processes its own type of data (API calls or permissions). As a result of convolution and max-pooling operations, the input data, i.e. behavioral patterns of Android app, is prepared for fully connected layers (FCL). It should be noted that the outputs from both sub-branch are merged, creating the first of three FCL. In order to produce nonlinear decision making, there is one hidden layer between the first and third FCL. The result is provided by the last layer consisting of two neurons.

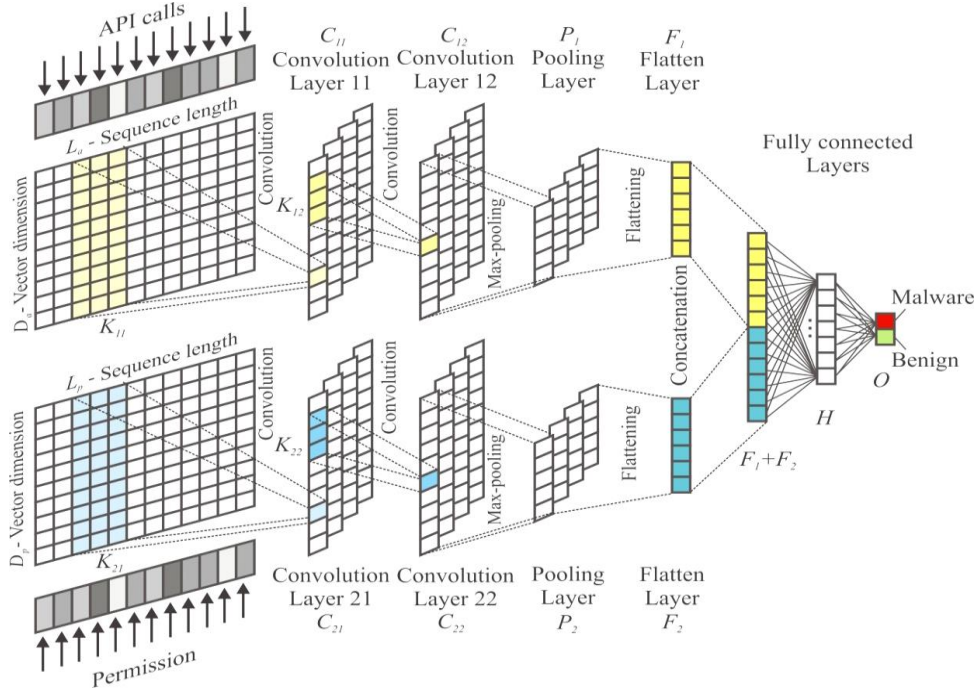


Fig. 4. The CNN Architecture for Android malware detecting

The proposed neural network architecture utilized an approach without convolutional and max-pooling layers alternating. This is due to the fact that after the next pair of CONV + POOL layers, the dimension of the data decreases, which leads to the loss of some information about the input object [19, 20]. In the proposed architecture, in each of the two sub-branch, the two convolution layers C_{11} and C_{12} , as well C_{21} and C_{22} , are placed one after the other, where the first convolution layers C_{11} and C_{21} highlight simple features that will be used by the layers C_{12} and C_{22} to represent higher-level behavior patterns. The input matrices with size $K_{11} \times D_a$ and

$K_{21} \times D_p$, respectively, are feed to the convolutional layers C_{11} and C_{21} . For layers C_{12} and C_{22} , the size of the convolution kernel is $K_{12} \times 1$ and $K_{22} \times 1$, respectively. Following each pairs of convolution layers there is placed one aggregation layer, which reduce the dimension of each type of feature. In order to transform the data into a one-dimensional vector, each sub-branch uses a Flatten layer. After concatenation the data of both sub-branches, the resulting vector with size $F_1 + F_2$ is feeds to FCL. The output layer consists of two neurons that accumulate the probability that a suspicious Android application belongs to one of two classes - malware or benign.

4 Experiments and Evaluation

For the purpose of verifying the effectiveness of the proposed method, a number of experiments were conducted. The first experiment involved selecting the optimal parameters for a convolutional neural network. We have considered several templates for neural network and train each of them. This process allowed us to choose the optimal network configuration. After defining the optimal neural network configuration we again have built the model and second experiment to verifying the effectiveness of Android malware detection have conducted.

A set of apk files that corresponded to malicious software or benign applications were selected as test data to evaluate the effectiveness of the proposed method. Malicious samples were obtained from the AndroZoo collection [21] while benign apps from [22]. There are 9198 malware and 7780 benign samples were used for the experiments. Thus, the total number of test data in training corpus C was 16978.

For each sample from the training corpus, the procedure of extracting API calls and a set of permissions was conducted. In order to obtain API calls list, at first apk files was decompiled and a set of smali files are obtained. Next, using a script in Python, an algorithm for extracting API calls from smali files was implemented. The set of Android permissions was obtained by simply parsing AndroidManifest.xml.

In order to create a vector representation of API calls the word2vec method was used, which involved training the neural network to obtain weights between the input and the hidden layer of neurons. The values for the hyperparameters for word2vec were as follows: dictionary for the API calls $V = 1184$ (i.e. the number of unique API calls observable in training corpus C), the size of the context window s for obtaining embedding of API calls was 6, the dimension of the feature vector for API calls (i.e. the dimension of input vectors for CNN) was 64.

To represent each permission in form of the feature vector we have selected the following options: dictionary for permissions $U = 168$ (the number of unique permissions observable in training corpus C), the dimension D_p of the feature vector for permissions was 49 ($D_p = U / 4 + 7$).

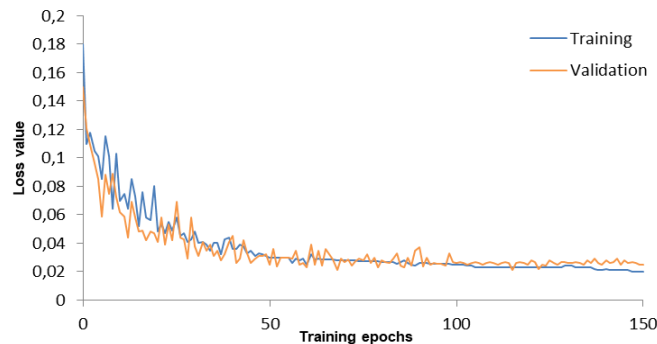
We also unify the length of the API call sequence and set of permissions for each sample from the training corpus. If the application has fewer features than the sequence length L_u or L_p , then the sequence of API calls or permissions of the app

was padded with zeros. then we pad a sequence of API calls or permissions with zeros. If the sequence length for API calls or set of permissions is greater than the value L_a or L_p , then the first L_a or L_p permissions or API calls values were selected from the given sequence.

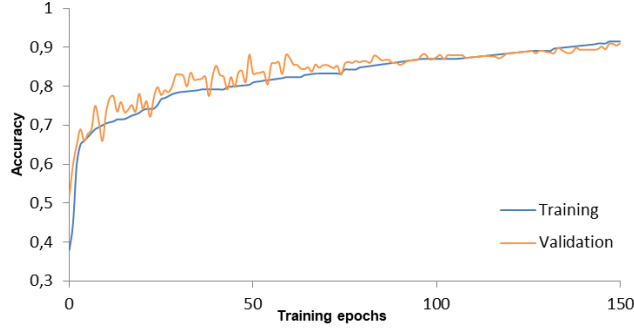
The first experiment involved selecting the most optimal parameters for a convolutional neural network. (fig. 4). To this end, the entire training corpus was divided into two groups: the training set 80% and the data for testing (validation) of the model 20%. The initial value of the number of epochs for training the network was 180 epochs. However, if during the network training, the performance did not change for 10 epochs, the training was terminated. To determine the best configuration of CNN eight templates of configuration options were considered (Table 1). Also for all templates the sequences length L_a and L_p are set to 200 and 50 respectively, and kernel size, padding, stride for $K_{11}, K_{12}, K_{21}, K_{22}$, are set to $\{3, 1, 1\}, \{3, 1, 2\}, \{2, 1, 1\}, \{3, 1, 2\}$ respectively. Each neural network was trained and validated. Based on the values of the loss function and accuracy, the optimal values of the network parameters were selected. Neural network training was stopped for 150 epochs, with a loss function of 0.01954. The accuracy value was 0.915. Thus, a set of parameters in template 1 was selected as the optimal neural network configuration. The training and validation process for optimal network configuration (template 1) are shown in Fig. 5.

Table 1. Sets of templates to determine the optimal configuration of the proposed convolution network

№	K_{11}	K_{12}	C_{11}	C_{12}	F_1	K_{21}	K_{22}	C_{21}	C_{22}	F_2
1.	3	3	64	128	64	2	3	64	128	64
2.	3	3	64	128	64	3	3	64	128	64
3.	2	2	64	128	64	2	2	64	128	64
4.	3	2	128	64	64	2	3	128	64	64
5.	3	3	128	64	64	3	3	128	64	64
6.	3	3	256	128	64	3	3	256	128	64
7.	4	4	256	128	64	4	4	256	128	64
8.	5	5	128	128	64	5	5	128	128	64



a)



b)

Fig. 5. The Process of neural network training and validation with optimal configuration: loss function (a); the value of accuracy (b)

The second experiment provided verifying the effectiveness of Android malware detection based on the model of the proposed convolutional neural network. The neural network weights were initialized with normal distribution. For all layers, except last, the ReLu activation function was selected. The neurons of the last layer were activated by a softmax function that simulates the probabilities of belonging suspicious app to one of the two classes. The neural network minimized the cross-entropy loss function. In order to reduce the impact of overfitting of the neural network between fully connected layers dropout regularization was used with parameter $p = 0.5$ (during testing, the dropout parameter was $p = 1.0$). The learning rate and the batches size were set at 0.001 and 64, respectively. Keras neural network library was used to implement the proposed network [23].

A 10-fold cross-validation was used to evaluate performance metrics. A 10-fold cross-check was used to calculate performance metrics. To this end, 90% of the entire set of C test data was used for model training and 10% for testing. This data selection procedure was performed ten times, each time selecting a different sequence for training and testing. This allows us to simulate a zero-day malware detection situation. The overall performance of the method was defined as the average of the performance indicators at each of the ten testing stages. After each stage of testing, the values of accuracy, precision, recall and Fscore were calculated as:

$$Accuracy = \frac{TP + TN}{TP + TN + FP + FN}, \quad (5)$$

$$precision = \frac{TP}{TP + FP}, \quad (6)$$

$$recall = \frac{TP}{TP + FN}, \quad (7)$$

$$Fscore = 2 \cdot \frac{precision \cdot recall}{precision + recall}, \quad (8)$$

where, TP – number of correctly detected malware, FN – the number of malware, wrongly classified as the benign programs, FP - the number of benign programs that were wrongly classified as the metamorphic viruses, TN – the number of benign programs that were correctly classified.

The results of evaluation of the proposed method effectiveness for detecting Android malware are shown in Table 2. During conducting of experiments the maximum value of detection accuracy was at 0.9412, while the minimum value was 0.9235. The average accuracy was observed at 0.9332 (which is almost the same as the Fscore), while the false positive rate was 3.3%.

Table 2. The results of evaluation of the proposed method effectiveness

№	Observations				Metrics			
	TP	FP	TN	FN	$Precision$	$Recall$	$Fscore$	$Accuracy$
1	8679	519	7283	497	0,9436	0,9458	0,9447	0,9402
2	8636	562	7268	512	0,9389	0,9440	0,9415	0,9367
3	8605	593	7259	521	0,9355	0,9429	0,9392	0,9344
4	8696	502	7262	518	0,9454	0,9438	0,9446	0,9399
5	8055	624	7236	544	0,9281	0,9367	0,9324	0,9290
6	8586	612	7093	687	0,9335	0,9259	0,9297	0,9235
7	8687	511	7249	531	0,9444	0,9424	0,9434	0,9386
8	8624	574	7078	702	0,9376	0,9247	0,9311	0,9248
9	8683	515	7296	484	0,9440	0,9472	0,9456	0,9412
10	8586	612	7093	687	0,9335	0,9259	0,9297	0,9235
Average	8584	562	7212	568	0,9385	0,9379	0,9382	0,9332

5 Discussion and Future Work

During developing the Android malware detection method, it was very important to design and implement not only the neural network architecture, but also to determine the values of hyperparameters that directly have impacting to computational complexity and detection accuracy. In the process of choosing hyperparameters, we had primarily guided by the principle of balancing detection accuracy and computational complexity. Of course, detection accuracy could be improved by increasing the number of consecutive convolution layers and the size of the input feature vectors. However, in this case, the computational complexity of detection method would increase significantly, which would not allow been it's used in real-time malware detection.

In addition, as a disadvantage, it can be noted that the presented method uses static analysis, which do not capable to detect obfuscated malware [24, 25]. To address this shortcoming and as a future study, we will adapt the convolutional neural network architecture to the data that will be obtained during dynamic monitoring of the behavior of the Android application. We are convinced that such combination of data will increase the detection efficiency of malicious Android applications.

6 Conclusion

The paper presents a method of detection Android malware with using a convolutional neural network. The proposed neural network is based on the principle of using mixed data, which represent the knowledge about API method calls and a set of permissions from the Android application. Word2vec technology was used to represent API calls in a vector space, which creates semantically similar feature vectors for related API calls. To represent a set of permissions, each unique permission is encoded as a binary feature that determines the presence or absence of permission in the input sequence. Obtained sequence is then broken down into nibbles and the code “8421” is applied with further normalization of the result. Both types of vectorized data are the inputs to the convolutional neural network.

The architecture of the proposed neural network consists of two separate parallel convolutional branches, each of which processes its own type of data. The outputs from both branches of the network are combined to form the input for fully connected layers, which determine the probabilities of belonging suspicious app to one of the classes – malware or benign.

A number of experiments involving 16978 Android applications were conducted to evaluate the effectiveness of the proposed method. According to the results of those experiments the optimal configuration of parameters for the convolutional neural network was selected and, on the basis of it, the metrics accuracy, recall, precision and F1 score had been evaluated. The average accuracy was observed at 93% with 3.3% of false positives.

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New Technique for Hiding Data Using Adaptively Generated Pseudorandom Sequences

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Abstract. This article explores the steganographic techniques of hiding information using direct spectrum expansion technology. Using noise-like pseudorandom sequences (discrete signals), it is possible to reliably hide information messages in redundant digital data (cover files), for example, images, video and audio files, etc. However, the correlation of discrete signals and cover files can be a problem; the extracted information messages can cover a lot of the number of errors. Our experiments (on still images) show that the error rate in the reconstructed information messages is very high. We offer a new technique when the statistical properties of covers are taken into account when generating discrete signals. In this case, it is possible to significantly reduce the error rate without introducing additional distortion in-to the cover.

Keywords: pseudorandom sequence, hidden information, direct spectrum spread technology, steganography

1 Introduction

Direct spread spectrum technology has traditionally been used in code division multiple access radio communication systems (CDMA). These techniques are used for a variety of reasons, including the establishment of secure communications, increasing resistance to natural interference, noise, and jamming, to prevent detection, to limit power flux density (e.g., in satellite down links), and to enable multiple-access communications [1-3].

The technology of direct spectrum expansion uses discrete noise-like sequences (discrete signals) to expand a usually narrowband information signal over a relatively wideband (radio) frequency range. The receiver correlates received signals to extract the original information signal.

Thus, the basic principle of direct spectrum spreading is the use of noise-like carriers and the bandwidth is much wider than that required for simple point-to-point communication with the same data rate. This allows you to get significant advantages in the organization of communication, for example [1-3]:

- Resistance to jamming (interference). High resistance to narrowband interference is provided;
- Resistance to eavesdropping. The selection of a particular pseudo-random sequence can be saved as a secret key. In this case, it is very difficult to find the right key and eavesdrop on the negotiations. In addition, when using very long pseudo-random sequences, it is possible to arrange communication at very low signal to noise ratios, which does not even allow the secret transmission of information to be detected;
- Resistance to fading. The expansion of the frequency band leads to an increase in the quality of communication, even in conditions of fading (attenuation) of the signal;
- Multiple access capability. A large number of sequences allows to increase the subscriber capacity of the communication system, i.e. after all, makes communication much cheaper.

Direct spectrum spreading technology can also be used for steganographic purposes, i.e. to hide information messages in redundant digital data (cover files), for example, in images, video and audio files, etc. Moreover, cover files are interpreted as noise in communication channels, and the number of different discrete signals determines the channel capacity of the steganosystem (similar to multiple access to CDMA).

This article explores the steganographic techniques of hiding information using direct spectrum expansion technology. We offer a new technique when the statistical properties of cover files are taken into account when generating discrete signals. This allows you to significantly improve individual performance indicators of the steganosystem. In particular, we manage to significantly reduce the bit error rate in the extracted informational messages.

2 Literature review

In the first works [4-7] on steganographic systems based on direct spectrum expansion, the fundamental possibility of hiding data in various cover files was shown, the main advantages of using pseudorandom sequences, as well as some dependences of the error rate in the restored messages and cover file distortions are shown. Subsequently, many techniques were finalized and improved. In particular, in [8], combined methods combining error correction, random positioning in pixels of a cover image, and direct-sequence spread spectrum (DSSS) spectrum expansion were investigated. In [9], concealment is implemented in the frequency domain, i.e. spreading modulation was applied to discrete cosine transform (DCT) coefficients. In [10], the implementation of the steganosystem was supplemented by several levels of security, including cryptographic transformations. In [11], aspects of the practical implementation of steganosystems when hiding information in audio files by the method of direct spectrum expansion are considered. In [12], steganoanalysis methods using video files and direct spectral expansion methods were studied. The work [13] is devoted to the use of steganographic security techniques for transmitting medical images and elec-

tronic medical records in teleradiology. Article [14] is devoted to a theoretical panalysis of the safety of steganosystems based on direct sequence spreading of the spectrum.

Thus, methods of direct expansion of the spectrum are used to conceal data in various multimedia files (images, video, audio, etc.). Moreover, transformations can be used both in the spatial domain [4-7] and in the field of orthogonal transformations, for example, in DCT [9]. At the same time, the main problem of using DSSS in steganography is the high level of errors in the restored messages.

3 Purpose and objectives of the article

The main goal of this work is to introduce a new technique for hiding informational messages in cover files using direct spectrum expansion and adaptively generated pseudorandom sequences. We propose a new approach consisting in the formation of noise-like sequences taking into account the statistical properties of cover files. The task is to ensure that each sequence does not correlate with the cover file used. This can significantly reduce the bit error rate in the extracted informational messages. Our experiments clearly confirm this.

The article is organized as follows. First, we briefly present the known information on the use of direct spectrum spreading technology in steganography (we use basic information from several articles and US patents), and also show that the practical failure to fulfill certain theoretical assumptions will lead to the guaranteed occurrence of errors in the restored information data. Our experiments on still images clearly demonstrate this, and the error rate remains very high even with amplification of the spreading signal and with a small number of hidden data. We also show examples of specific images of covers, as well as an assessment of their distortions at various parameters of the steganosystem. Finally, we propose a new technique for hiding information, which is based on the obligatory fulfillment of the theoretical assumption about the uncorrelatedness of extension sequences and cover files. The experiments presented in the article show that in practical implementation it is really possible to significantly reduce the bit error rate. Preliminary results were abridged at the conference [15].

4 Hiding data in images using direct spread spectrum technology

As a prototype of an improved method of hiding data in cover images, the technique proposed in the dissertation by L. Marvel was selected, described in detail and studied in [6, 7, 16, 17]. Let's consider it in more detail.

The method of concealing data using the direct spread spectrum, proposed in US patent [17], based on the fact that (on the transmission side after encryption and noise immunity coding) separate blocks $m_i = (m_{i_0}, m_{i_1}, \dots, m_{i_{k-1}})$, $i = 0, \dots, N-1$ of data of

information message $m = (m_0, m_1, \dots, m_{N-1})$ the blocks are modulated by noise-like discrete signals with the help of appropriate devices $\Phi_i = (\phi_{i_0}, \phi_{i_1}, \dots, \phi_{i_{n-1}})$, $\Phi_i \in \Phi = \{\Phi_0, \Phi_1, \dots, \Phi_{M-1}\}$, $k \leq M$, with a base $B = TF$, where T is the duration of the signal element ϕ_{i_j} , F is the frequency band of the signal Φ_i . Since $F = n \frac{1}{T}$ we have $B = n \gg 1$ and the signal base sets the frequency spread of the frequency band of signal Φ_i with respect to elementary signals ϕ_{i_j} and / or m_{i_j} . As a result, a modulated information signal block is generated for each m_i information block

$$E_i = \sum_{j=0}^{k-1} m_{i_j}^* \Phi_j, \quad (1)$$

where

$$m_{i_j}^* = \begin{cases} +1, m_{i_j} = 1; \\ -1, m_{i_j} = 0; \end{cases}$$

which, according to statistical properties, takes the form of a random (noise-like) sequence

$$E_i = \left(\sum_{j=0}^{k-1} m_{i_j}^* \phi_{j_0}, \sum_{j=0}^{k-1} m_{i_j}^* \phi_{j_1}, \dots, \sum_{j=0}^{k-1} m_{i_j}^* \phi_{j_{n-1}} \right),$$

and due to the large base of discrete signals, the frequency spectrum is spreaded by $B = n$ times.

The resulting modulated message E_i is supplied to an alternating device on which the elements of E_i are mixed with the corresponding rule f by means of a secret key K_1 . The obtained data $\overline{E}_i = f(E_i, K_1)$ using the appropriate device is added to the data of the image C_i (digital image data in the spatial domain) according to the rule: $S_i = C_i + \overline{E}_i \cdot G$, where $G > 0$ is the gain of the expansion signal, which sets the "power" of the hidden blocks of information messages.

The obtained data S_i is supplied to the quantization device, which performs a certain transformation to store the primary dynamic range of the cover image, resulting in the formation of separate blocks of the steganogram \overline{S}_i and the cover $\overline{S} = \overline{S}_0 \cup \overline{S}_1 \cup \dots \cup \overline{S}_{N-1}$, which is transmitted to the receiving side.

On the receiving side, the resulting steganogram blocks \overline{S}_i after filtration, are, supplied to a reverse interleaving device, on which the elements of the filtered blocks

of the stegogram $\overline{S_i}$ are mixed by rule f^{-1} , which is an inverse rule of alternation f on the transmitting side. The extraction of blocks of information data is carried out using a correlation receiver, which calculates the value of the correlation coefficient obtained after the reverse alternation of data $S^*_i = f^{-1}(\overline{S_i}, K_1)$ and corresponding discrete Φ_j , signals identical to those used on the transmitting side:

$$\rho(S^*_i, \Phi_j) = \frac{1}{n} \sum_{z=0}^{n-1} S^*_{i_z} \phi_{j_z}. \quad (2)$$

Since $S_i = C_i + \overline{E_i} \cdot G$ we have:

$$\frac{1}{n} \sum_{z=0}^{n-1} S^*_{i_z} \phi_{j_z} \approx G \cdot \frac{1}{n} \sum_{z=0}^{n-1} E_{i_z} \phi_{j_z} + \frac{1}{n} \sum_{z=0}^{n-1} C_{i_z} \phi_{j_z}$$

Suppose that the data block of the image block C_i has a random statistical structure, that is, suppose that the second term on the right side of expression (2) is close to zero and can be ignored. Then we have:

$$\rho(S^*_i, \Phi_j) \approx G \cdot \sum_{u=0}^{k-1} m^*_{i_u} \rho(\Phi_u, \Phi_j). \quad (3)$$

Since all sequences of the set Φ are formed by a pseudorandom sequence generator initiated by a secret key K_2 , the corresponding discrete signals are weakly correlated, that is, at $u \neq j$ we have $\rho(\Phi_u, \Phi_j) \approx 0$.

According to this, all terms, except case $u = j$, in the right-hand side of equation (3) can be ignored. Where do we have:

$$\rho(S^*_i, \Phi_j) \approx G \cdot m^*_{i_j} \cdot \frac{1}{n} \sum_{z=0}^{n-1} (\phi_{j_z})^2 = G \cdot m^*_{i_j} = \begin{cases} +G; \\ -G. \end{cases} \quad (4)$$

The corresponding value of the seized data is taken with a threshold device according to the calculated correlation coefficient.

Since $G > 0$ and $n > 0$ of $\rho(S^*_i, \Phi_j)$ character in (4) depends only on $m^*_{i_j}$, from where we have:

$$m^*_{i_j} = \text{sign}(\rho(S^*_i, \Phi_j)) = \begin{cases} -1, & \rho(S_i, \Phi_j) < 0; \\ +1, & \rho(S_i, \Phi_j) > 0. \end{cases} \quad (5)$$

If $\rho(S^*_i, \Phi_j) = 0$ in (5) we will assume that the hidden information has been lost (erased). Separate blocks of data are formed from the extracted data on the receiving side $m_i = (m_{i_0}, m_{i_1}, \dots, m_{i_{k-1}})$, $i = 0, \dots, N-1$ of information messages

$$m = (m_0, m_1, \dots, m_{N-1}), \text{ where } m_{i_j} = \begin{cases} 1, m^*_{i_j} = +1; \\ 0, m^*_{i_j} = -1; \end{cases} \text{ of which information messages}$$

are generated after noise immunity decoding and decryption of the extracted data.

The secret key K_2 sets the rule for the formation of pseudorandom sequences $\Phi_i = (\phi_{i_0}, \phi_{i_1}, \dots, \phi_{i_{n-1}})$, which are formed by the corresponding generator and are used as noise-like discrete signals $\Phi_i \in \Phi = \{\Phi_0, \Phi_1, \dots, \Phi_{M-1}\}$ from the ensemble (set) Φ of power M .

The encryption and decryption rule on the transmitting and receiving side is initiated by the secret key K_3 .

The use of encryption and alternation devices in the process of hiding and retrieving data can improve the statistical properties of the modulated message E_i , ie to bring it closer to a random sequence. The use of noise immunity coding devices can improve the reliability of the transmission of information messages $m = (m_0, m_1, \dots, m_{N-1})$ during steganographic conversions.

5 Experimental researches

The disadvantage of the prototype under consideration is that in the process of steganographic hiding, the statistical properties of the blocks of the image C_i , are not taken into account, that is, the digital image data can be correlated with the applied discrete signals, which will lead to an error when extracting information data on the receiving side.

So, for example, if the correlation coefficient of the i -th block C_i of the image will be higher behind the module and opposite in value of sign $G \cdot m^*_{i_j}$, that is, when the second summand in the right part of expression (2) will be higher in module and opposite in value of sign of the first summand (and the condition of mutual orthogonality of applied discrete signals will be fulfilled), it is guaranteed that an error will be the result at data extract according to rule (5). In practice, as our researches have shown, such cases occur very often. This is due to the fact that the digital data of real images used to hide information messages do not have a random statistical structure, that is, the applied assumption in the transition from formula (2) to formula (3) is not fulfilled in practice and is false. Typically, steganographic hiding uses realistic images and the corresponding digital data is not a random process, and even in its statistical properties are not similar to pseudorandom sequences. The

corresponding values of the correlation coefficient $\rho(C_i, \Phi_j) = \frac{1}{n} \sum_{z=0}^{n-1} C_{iz} \phi_{jz} \neq 0$, and

can take large amplitude ($|\rho(C_i, \Phi_j)| \gg 1$) and random values. In this case, it is possible to increase the reliability of the extracted data only by applying low-speed noise immunity codes (as in the prototype discussed above [6, 7, 16, 17]), which leads to a decrease in the relative transmission rate of information, or an increase in the gain G , which leads to an increase in the introduced errors.

To confirm this fact, Fig. 1 shows the empirical estimates of BER dependence in message recovery using the considered prototype method (interrupted line). The $G = 4$ gain was applied, and the number of bits k , hidden in one block C_i of the cover image varied from 1 to 255. Fig. 2. shows empirical estimations of dependence of the average proportion of introduced errors (in relation to the dynamic range of 256 levels) in the cover image with respect to the number of bits embedded in one element of the cover. From the given dependencies (Fig. 1, 2, interrupted line) it is visible, that at entering errors in the cover image below a visual threshold of human sensitivity (2-3%) it is possible to hide no more than 10 bits of data in one block of the image C_i . But even with such an insignificant amount of hidden data, BER takes the value 0.05..0.25, which requires the use of low-speed noise immunity codes with the permission to correct multiple errors.

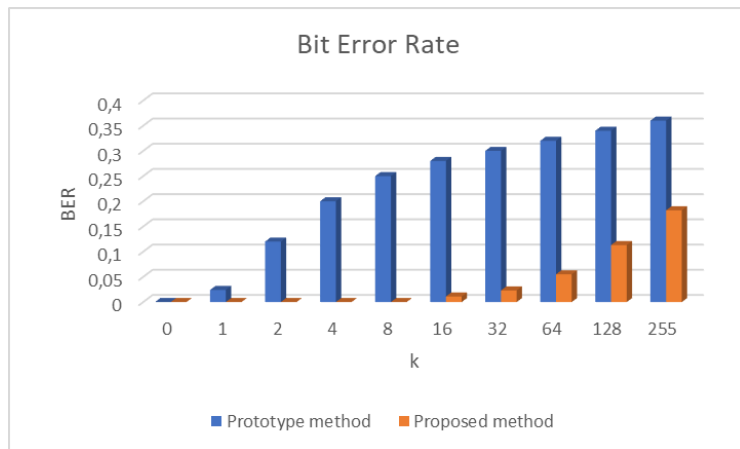


Fig. 1. Bit error rate in recovered messages depending on message size

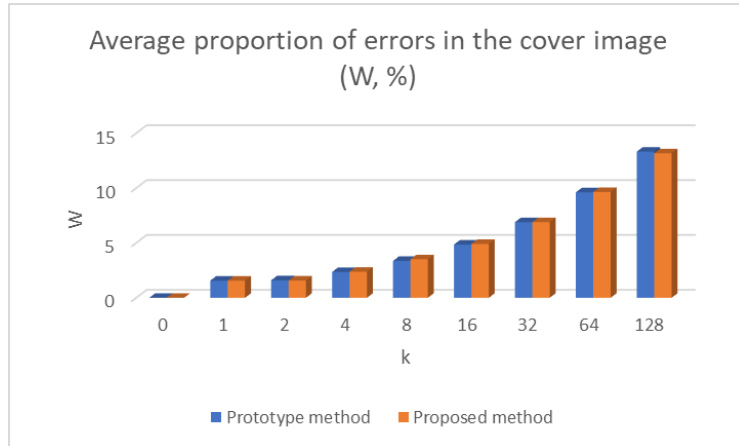


Fig. 2. The proportion of distortion introduced into the cover image depending on the size of the message

In Fig. 3, 4 show, accordingly, the obtained empirical estimates of the BER dependence when restoring the messages and the dependence of the average fraction of the input errors on the G gain values using the considered prototype method (intermittent lines). At the same time, $k = 4$ bits of information data were embedded in one block C_i of the cover, and the gain G changed from 1 to 8. From the given dependencies (Fig. 3, 4, interrupted line) it is visible, that at value of gain $G > 6$ hiding of the information data leads to entering of errors, part of which (relative to a dynamic range) is above a visual threshold of human sensitivity (2-3%). That is, the fact of hiding data in the image turns out to be a visual observation and steganographic hiding with these parameters is not reasonable. But at $G \leq 6$ gain value, there is a large number of errors when extracting individual data bits from the spatial area of the image corresponding to $BER \geq 0,2$.

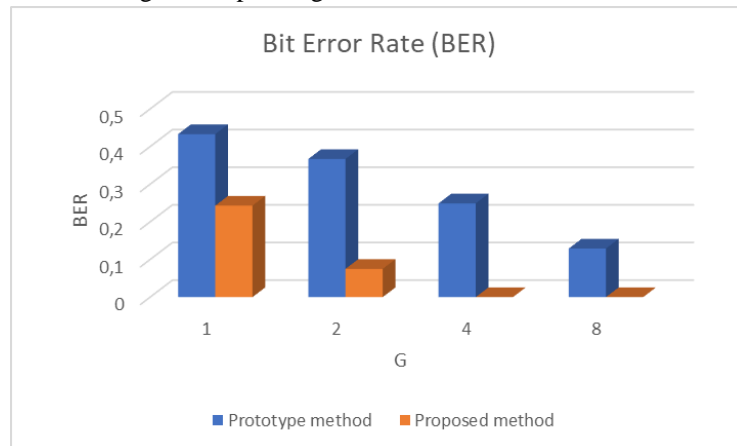


Fig. 3. Rate of bit errors in recovered messages depending on the gain factor

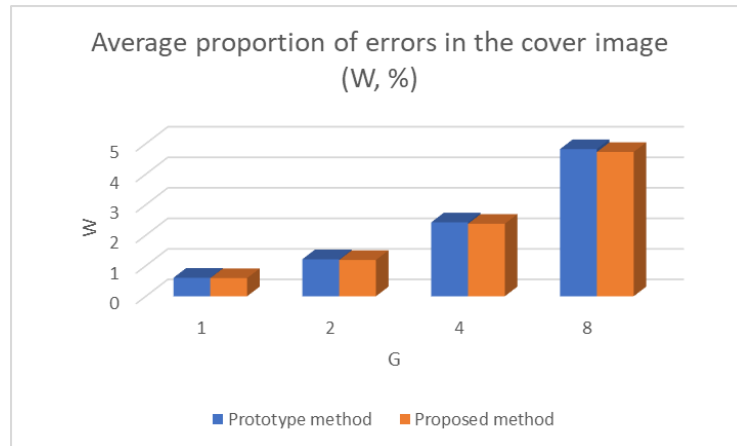


Fig. 4. The proportion of introduced distortion in the cover image depending on the gain factor

In Fig. 5-7 shows examples of images used in research:

- Fig. 5 – original image;
- Fig. 6 – image with hidden messages using prototype method;
- Fig. 7 – image with hidden messages using the proposed method.

Data hiding is done with the following parameters: $G = 4$, $k = 4$.



Fig. 5. Original image



Fig. 6. Example of cover image (using prototype method)



Fig. 7. Example of cover image (using the proposed method)

6 Proposed data hiding technique

Our task is based on the following: by taking into account the statistical properties of cover C_i , significantly reduce the BER of hidden data. Indeed, the introduction of additional constraints on the correlation coefficient of the discrete signals used and

individual fragments of the image can significantly reduce the number of errors when recovering the message on the receiving side.

This problem is solved due to the special (we call adaptive) formation of pseudorandom sequences $\Phi_j = (\phi_{j_0}, \phi_{j_1}, \dots, \phi_{j_{n-1}})$, taking into account the statistical properties of these blocks of cover C_i . That is, the value of the correlation coefficient $\rho(C_i, \Phi_j)$ for all $i=0, \dots, N-1$ and for all $j=0, \dots, M-1$ by the module should not exceed some predetermined value ρ_{\max} (value of the set threshold):

$$\left| \rho(C_i, \Phi_j) \right| = \left| \frac{1}{n} \sum_{z=0}^{n-1} C_{i_z} \phi_{j_z} \right| \leq \rho_{\max}. \quad (6)$$

Thus, the formation of $\Phi_j \in \Phi = \{\Phi_0, \Phi_1, \dots, \Phi_{M-1}\}$ sequences is performed by a pseudo-random rule, which is initiated by the secret key K_2 , and taking into account conditions (6) for all $i=0, \dots, N-1$ and all $j=0, \dots, M-1$.

In this formation of discrete signals, each sequence of the set of $\Phi = \{\Phi_0, \Phi_1, \dots, \Phi_{M-1}\}$ will not be correlated (up to the set limit) with any block of the cover image, and, accordingly, the correlation coefficient of the i -th block C_i of the cover on the module will never be higher than the module and the opposite in sign ρ_{\max} . In accordance with this (and when the conditions of mutual orthogonality of the applied discrete signals) the second term in the right part of expression (2) may exceed in module and be opposite in sign to the first term only when $\left| G \cdot m_{i_j}^* \right| < \rho_{\max}$. It is in this case that an error of data extraction will happen, but the probability of such an event will be much less than in case of an error of data extraction in the prototype method. If the value of the ρ_{\max} threshold is lower than the G gain value, i.e. when the unequal is performed $\left| G \cdot m_{i_j}^* \right| > \rho_{\max}$ the error will not occur at all, i.e. an unmistakable transfer of secret information will be achieved.

In Figs. 1-6, solid lines show empirical estimates of the probability properties of steganographic concealment using the proposed method, which confirms our conclusion:

- in Fig. 1 shows the bit error rate in the recovered messages depending on the size of the message;
- in Fig. 2 shows the proportion of distortion introduced into the cover image depending on the size of the message;
- in Fig. 3 shows bit error rate in the recovered messages depending on the gain factor;
- in Fig. 4 shows the proportion of distortion introduced into the cover image depending on the gain factor.

7 Discussion of the results

From the above dependencies in Fig. 1, 2 (solid line) shows that when making errors in the cover image lower than the visual threshold of human sensitivity (2-3%) manages to embed no more than 10 bits of data in one block of the C container (as in the prototype method). But with so a number of hidden data, the BER value is much less than 0.1 and several dozen times less than in the prototype method.

From the given dependencies in the fig. 3, 4 (solid line) can be seen that at the value of gain hiding information data in the cover image leads to the introduction of errors whose fate (in relation to the dynamic range) is higher than the visual threshold of human sensitivity (2-3%) as well as in the method prototype. At $G \leq 6$ values, the errors introduced into the cover image are lower than the human visual sensitivity threshold, i.e. they are invisible. In compared with the method-prototype, there is a significant reduction in the number of errors when extracting individual data bits from the spatial area of the image. In addition, at the H gain value, there is a total non occurrence of errors in remote data, which confirms the above conclusion about the error-free transmission of hidden information. Indeed, if $G = 4$ then the inequality is being realized $|G \cdot m^*_{i_j}| > \rho_{\max}$, that is, assuming the validity of the mutual orthogonality of the applied discrete error signals, no errors occur at all and an error-free transmission of hidden information is achieved.

From the given dependencies in the fig. 5, 6 (solid line) shows that in almost all cases, when hiding data the proposed method is a gain in relation to the method-prototype (interrupted line). Thus, when the number of k bits hidden in one element of the cover image increases, as well as in the prototype method, there is an increase in the probability of false data extracted on the receiving side. However, this increase is much slower than in the prototype method. As the G gain increases, the probability of false data extraction decreases, but the proposed method (solid line) has significantly improved probabilistic properties than the prototype method (interrupted line).

8 Conclusions

Spread spectrum technologies are traditionally used in multiple access radio communication systems. Direct-sequence modulation makes the transmitted signal wider in bandwidth than the information signal. The resulting transmitted signal resembles white noise limited in bandwidth. This noiselike signal is used to accurately restore the source data on the host side by multiplying it by the same expansion sequence. This process is mathematically a correlation, i.e. on the receiving side the recovery of information data is performed by calculating the correlation coefficient of the accepted sequence and the spreading sequence.

Application of the technology of direct spread-spectrum in radio communication systems allows obtaining specific advantages: resistance to jamming (interference); resistance to eavesdropping; resistance to fading; multiple access capabilities. Some

radiocommunication industry standards take advantage of these advantages. However, this technology can also be successfully applied in steganography. Excess data (images, audio and video files, text documents, etc.) are interpreted as noise in a communication channel. The task is to hide information data in such a way that redundant data (cover files) are not distorted, i.e., photo or video images are visually indistinguishable from the original data. The technology of direct spread-spectrum is suitable for this very well.

The main theoretical assumption that explains the operation of this technology is the uncorrelation of the spreading sequence and noise in the communication channel. In radio communications systems with white noise, this assumption is fulfilled and there are few errors on the receiving side. In steganographic systems, however, this assumption may not work. Noise is understood here to be excess digital data, for example, it can be realistic images. And such cover files can strongly correlate with the spreading sequence. As a result of the correlation reception, a large number of errors occur when restoring information messages. We offer an effective way to reduce such errors. In fact, we offer a new way to form spreading sequences that takes into account the statistical properties of cover files. We call this method adaptive. As a result, we have a set of spreading sequences that do not correlate with cover files and almost no errors occur when restoring information messages. Experiments show that this is indeed the case. Our approach is much more efficient. Thus, a specific technical result is achieved, namely: by taking into account the statistical properties of the digital data of the cover images (in the adaptive formation of pseudorandom sequences) it is possible to significantly reduce the number of errors in the recovery of information data on the receiving side.

A promising trend is to study the properties of steganosystems using complex discrete signals with special correlation properties. For example, we want to use sequences from our previous work [18-19] to hide information in cover images.

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Cryptographically Properties of Random S-Boxes

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Abstract. The results of studies of the properties of random permutations carried out with the participation of the authors are generalized. It is shown that random substitutions overwhelmingly have good cryptographic, and in particular, algebraic properties. The prospects of using random S-blocks to build block symmetric ciphers with improved dynamic rates of arrival to random substitution are substantiated. A refined model of random substitution and the corresponding criteria are proposed, with the help of which one can verify the suitability of substitutions generated randomly for use in modern cipher designs. It is a check, since with a very high probability the checked substitutions will be suitable.

Keywords: algebraic properties of S-blocks, Boolean functions, cryptanalysis, random S-boxes, algebraic immunity of S-boxes, algebraic degree of S-boxes, dynamic indicators of a cipher, model of random substitution

1 Introduction

In accordance with the new methodology for assessing the strength of symmetric block ciphers, developed in [1], BSC strength indicators are independent of S-blocks included in the cipher cyclic functions. Substitution transformations (S-blocks) affect only the number of cycles the ciphers arrive at the state of random substitution, and then only within, as a rule, one cycle. A huge number of publications devoted to the construction of S-blocks with high cryptographic performance are aimed at practically winning one cycle in the encryption procedure and increasing other cryptographic performance of ciphers according to the authors' assumptions. In particular, they strive to apply S-blocks with the smallest possible values of differential and linear probabilities (random S-blocks have increased values of differential and linear probabilities and therefore require an additional cycle to arrive at a random substitution).

It turns out that the used constructions of cycle functions provide activation on the first cycles of far from the whole set of S-blocks.

We also note that in accordance with the new methodology for assessing the strength of block symmetric ciphers, all ciphers after several initial encryption cycles,

regardless of the S-blocks used, become random substitutions: For example, Rijndael-128 comes to the state of random substitution for four cycle [2].

A natural question arises. And why all this colossal work on the selection and construction of “optimal” S-blocks, if as a result, in all cases, regardless of the S-blocks used, the same result is obtained (the same values of the maximums of differential and linear probabilities are obtained)?

Thus, it turns out that the price of using S-blocks with special properties is actually reduced only to reducing the number of cycles of arrival of ciphers to the state of random substitution (for one cycle). Other special indicators are also leveled when ciphers acquire random substitution properties.

So the idea came up to build an encryption transformation (cipher) with more efficient cyclic functions, allowing increasing the number of activated S-blocks in the first cycles in comparison with traditional methods and thereby switch to using random S-blocks in ciphers without any loss of strength any significant selection. In fact, we are talking about using S-blocks directly from the output of the random permutation generator.

This idea was implemented in the SHUP cipher (our work [3]). The loop function in this cipher is constructed using controlled settings. In this case, the substitution of the cyclic function is connected in a chain, so that the sum of two current segments of the input (folded with the corresponding segment of the cyclic key) and the output of the previous S-block is fed to the input of the current S-block, and the output of the last S-block modulo two with the output of the first or all previous S-blocks.

As a result, the definition of the very concept of a random S-block becomes relevant and evaluations of its cryptographic performance.

2 Formulation of the problem

In our works, we have long turned to the study and discussion of approaches to the design of S-blocks with high cryptographic indicators and ourselves conducted searches and studies in this direction. Note that to date; we can already count a huge number of publications devoted to this problem [4-6] and many others. There is simply not enough space to mark them. An approach based on algebraic methods for describing such constructions can be considered the most developed.

The analysis performed in our work [7-9] and others showed that, despite the beautiful mathematical apparatus that allows us to carry out a rigorous justification of a number of properties of the constructed S-blocks, the proposed approaches either give solutions oriented to certain classes of ciphers (for example, DES-like), often not without weaknesses, or turn out to be quite difficult for practical implementation, not to mention their inherent limitations. For example, the method works only for odd-degree S-blocks or for asymmetric S-blocks. Moreover, it is practically impossible to build S-blocks with simultaneously high all the indicators noted above. For a number of them, the constructed S-blocks are far from optimal.

In our works (here you can point to a work of a generalizing nature [7,9]) at the time, a different approach to the construction (selection) of suitable S-blocks was jus-

tified, based on the selection of random permutations using a system of criteria. In our subsequent studies of the properties of random permutations [10-11, etc.], this approach was further developed.

In this work, the task is to summarize the available information on random permutations and justify the prospects of their use in constructing symmetric block ciphers with improved dynamic rates of arrival at random permutations.

3 Literature review

It should be noted that there are practically no foreign publications devoted directly to random S-blocks in Google. There are only publications with our participation [7-9] and work with references to the use of random permutations in ciphers. The bulk of the work is the work devoted to the methods of forming S-block structures with improved cryptographic indicators [12-14] and many others. In work [15], a large number of publications in this direction were analyzed in sufficient detail. In the cited works, new techniques for the formation (construction) of S-blocks with improved cryptographic indicators are considered, and there are even works on the selection of random substitutions using a system of criteria close to our proposals. Only all the same, in these works we are talking about the selection of permutations according to strict criteria. And we will be talking about checking (control) substitutions from the output of the random substitution generator, and our criteria will be significantly milder than the proposed ones. Returning to the results of the analysis of the results of the noted works, we will again use the materials of [7], which fix our position at the time of their implementation. They come down to the following:

1. The current approaches to the construction of S-blocks for symmetric block ciphers are primarily aimed at ensuring minimum values of the differential DP_{\max} and linear probabilities LP_{\max} . And in this direction significant success has been achieved. S-block constructions with limit and theoretically minimum possible values of DP_{\max} and LP_{\max} close to them were implemented.

2. There is a thoroughly developed apparatus for evaluating cryptographic indicators (properties) of Boolean functions, with the help of which you can describe the transformations carried out by S-blocks. The approaches and rules by which the resulting cryptographic indicators of individual Boolean functions included in

S-block can be converted into indicators of the entire transformation (S-block) as a whole. Although very much attention is paid in the literature to the development and application of Boolean functions of the mathematical apparatus of the mathematical apparatus of S-blocks for evaluating cryptographic indicators, nevertheless, this algebraic approach for S-block constructions actually used in ciphers has not become decisive. Moreover, the S-block constructions used in modern ciphers have far from the best in some indicators, and in some of them even low cryptographic properties of the Boolean functions included in them. Therefore, the main (main) indicators are actually optimized, to the detriment of the secondary ones. These basic indicators include the values of the maxima of the differentials and displacements (δ -uniformity and

non-linearity), as well as the values of the algebraic degree and, more recently, the values of algebraic immunity.

If the values of the maxima of the differentials and displacements (δ -uniformity and non-linearity) can be determined without the apparatus of Boolean functions, then the last two indicators, algebraic degree and algebraic immunity, already require the use of the mathematical apparatus of Boolean functions.

3. The results obtained indicate that “good S-blocks (S-blocks with high cryptographic indicators), at least with respect to the main group of the marked criteria), as a rule, can be obtained by exhaustive search methods for S-blocks of degree 256 (byte S-blocks) is very difficult (requires significant computing resources). Therefore, all real developments to build large (byte) S-blocks were initially based on methods that could most likely be considered regular. So in our works of that time it is noted that the use of separate sentences available in publications, in particular, proposals of K. Nyberg [13], looks more progressive for building S-blocks. They found practical application in designs

S-blocks used to create many modern block symmetric ciphers (Rijndael, Camellia, ADE, Labyrinth and some others). In the IDEA NXT cipher, we took the path of building byte S-blocks based on the use of a three-byte composition -blocks, followed by the selection of the best candidate and the like. The elapsed time has made adjustments to the current state of the issue. The time has shown that random S-blocks really deserve more serious attention, as was noted above.

It is worth recalling here that when developing the new standard of Ukraine for the Kalina cipher, the developers have already taken the path of using S-blocks selected from randomly generated permutations with higher non-linearity indicators compared to Rijndael ciphers.

We supplement these conclusions with one more.

4. The experiments performed show that almost all S-blocks used in modern ciphers do not fit into the frames of S-blocks of a random type.

Our interest is focused on using directly randomly generated S-blocks in block symmetric ciphers without any restrictions. The developed approach is based on ideas from [1], devoted to the development of a new methodology for assessing the resistance of block symmetric ciphers to attacks of differential and linear cryptanalysis.

The main result of research in this direction was the substantiation of the position that the resistance indicators of modern block symmetric ciphers to attacks of differential and linear cryptanalysis do not depend on the properties of the used S-blocks (with the exception of their degenerate structures). S-block indices influence even within a single cycle the minimum number of cycles the cipher arrives at the state of random substitution (to the stationary values of the maximums of the differential and linear probabilities of the cipher).

The central point of the developed approach is the construction of new constructions of cyclic functions of block symmetric ciphers, which allow increasing the number of activated S-blocks in the first encryption cycles [3] and others. It is the increase in the number of activated S-blocks in the first cycles that allow substitution structures of a random type to be used in ciphers without decreasing the strength. In this work, it is supposed to describe the main stages of the birth of the methodology for

using random S-blocks when constructing ciphers and defining the concept of random substitution.

4. A brief overview of our results.

This section contains materials on the justification (study) of the properties of random permutations and methods (criteria) for their selection, obtained with the participation of the authors of this work. Materials are combined under the general idea of forming a random substitution model.

The following are extracts from our work.

We first recall the results of studying the laws of the distribution of inversions, increases and cycles of random permutations of degree $n \geq 4$ and reduced to 16-bit inputs of models of modern ciphers (our works [16]). It was found that they are distributed in accordance with the theory of random permutations according to the normal laws of probability distribution with corresponding numerical characteristics determined by the degrees of permutations [17].

On the basis of these results, the concept of random permutation was introduced, which was associated with checking the correspondence of combinatorial exponents of substitutions (the number of inversions, increases, and cycles) with the numerical characteristics of the asymptotic distribution laws of these exponents for random permutations [7,9,18].

Next, the distribution laws of differential and linear exponents of permutation transformations [19,20] were established with a refinement [21]. We recall here the theorems proved in [20-21] that determine the distribution laws of transitions XOR of random permutation tables and the distribution laws of displacements of linear approximation tables of random permutations. From the work [19]:

Statement 1. For any non-zero fixed $\Delta X, \Delta Y \in Z_2^m$, assuming that the substitution π is chosen equally from the set S_2^m и $1 \leq k \leq 2^m - 1$,

$$\Pr(\Lambda_\pi(\Delta X, \Delta Y) = 2k) = \binom{2^{m-1}}{k} \cdot \frac{k! \cdot 2^k \cdot \Phi(2^{m-1} - k)}{2^m!}, \quad (1)$$

where the function $\Phi(d)$ is determined by the expression

$$\Phi(d) = \sum_{i=0}^d (-1)^i \cdot \binom{d}{i}^2 \cdot 2^i \cdot i! \cdot (2d - 2i)!. \quad (2)$$

Here, ΔX and ΔY – are the input and output differences of the encryption conversion.

In [22] it is shown that formulas (1) and (2) correspond to an approximation in the form of a Poisson law of probability distribution of XOR transitions of tables of random substitutions:

$$\Pr(\Lambda_{\pi}(\Delta X, \Delta Y) = 2k) = e^{-1/2} \cdot \frac{1}{2^k \cdot k!}.$$

From our work [20]:

Theorem 1: *Let $\lambda(\alpha, \beta)$ be a random number that corresponds to the value of the cells of the linear approximation table of the substitution when the substitution π is chosen equally from the set S_2^n and the mask α, β nonzero. Then $\lambda(\alpha, \beta)$ for whole values of k , $0 \leq k \leq 2^{n-1}$ it takes only even values and the probability $\lambda(\alpha, \beta) = 2k$ determined by the expression*

$$\Pr(\lambda(\alpha, \beta) = 2k) = \frac{(2^{n-1}!)^2}{2^n!} \cdot \binom{2^{n-1}}{k}. \quad (3)$$

In the robot [23], it is shown that formulas (3) are approximated by the normal law, which can be considered Theorem 3 of the robots. Here you will go for number 2.

Theorem 2: *For a random n -bit substitution with $n \geq 5$ the imbalance $\text{Imb}(v, u)$ of the approximation is a random value with a distribution that can be approximated as*

$$\Pr(\text{Imb}(v, u) = z) \approx 2Z\left(\frac{z}{2^{(n-2)/2}}\right) \quad (4)$$

for z even and zero for z odd

If we substitute $z = 2x$ in (4), then it can be rewritten as

$$\Pr(\text{Imb}(v, u) = 2x) \approx Z\left(\frac{x}{2^{(n-4)/2}}\right),$$

that is, the imbalance $\text{Imb}(v, u) = z$ at $z = 2k$ corresponds to the value of the cell in the LAT table $\lambda(\pi) = 2k$

On the basis of these results, a model of random substitution was substantiated and studied in the form of a set of criteria for the proximity of combinatorial indices, as well as the laws of the distribution of transitions of differential and displacement tables of linear approximations of substitutions to the standard ones, which were considered by the corresponding laws of random substitutions [24].

Much attention has been paid to the use of algebraic methods for describing substitution transformations using the Boolean mathematical apparatus. In particular, the algebraic indices of the S-blocks of most known ciphers were determined.

As a result, was concluded that, although in the modern literature, much attention is paid to the development and application for the estimation of cryptographic indices of S-blocks of algebraic methods based on the mathematical apparatus of Boolean

functions, nevertheless, this algebraic the approach for many known S-block designs has not been decisive. Moreover, the S-block constructions used in modern ciphers do not have much better, but rather a number of indicators and rather low cryptographic properties of Boolean functions included in them. The real designs of S-blocks are built, rather, on the basis of indicators that can be determined (calculated) without the involvement of the Boolean function apparatus (although there is a direct relationship of some of these indicators with the properties of Boolean functions of S-blocks).

It turned out that the use of substitutions selected using the developed randomness criteria did not lead to any noticeable advantages.

Finally, we note the work on the construction of laws for the distribution of maxima of XOR table transitions and offsets of linear approximation tables [25,26]. For the byte substitutions, the corresponding extremal log-Weibull distributions were constructed. Using them, the values of the maxima of the differential tables and the offsets of the linear approximations of the byte random substitutions were substantiated. For differential tables of byte substitutions, the values of the maxima that occur most times are 8-10, and for the linear approximation tables it is 32-34.

However, it was not possible to find any particular advantages of substitutions selected with even rigid criteria used. By their cryptographic index, which are determined by known methods, including algebraic, they are not particularly distinguished against the background of other known structures. Therefore, all considered criteria for the selection of random substitutions in the submitted version had to be abandoned.

We then conclude that the Boolean function of the Boolean function is poor in relation to the use of S-blocks in modern ciphers.

Today, however, it can be noted that S-blocks of the Kalina-2 cipher, and some other modern ciphers, as the developers themselves noted, were chosen from random substitutions. S-blocks with high nonlinearity (125) and high algebraic immunity of 3 [27] have been sought, that is, the use of the Boolean algebra mathematical apparatus and is now receiving much attention when evaluating the cryptographic indices of S-blocks.

5. Algebraic indicators of random S-blocks.

However, we have chosen another way to choose S-blocks to use in ciphers. So, in the end, we move to a more refined mathematical model of random substitution, built on the properties of a sample of random substitutions (this model incorporates the found differential and linear laws of the distribution of transitions of the corresponding substitution tables) and constructed the extremal distributions of the XOR tables of transitions.

Therefore, attention is further focused on the use of random substitutions in the ciphers, that is, directly S-blocks from the output of the random substitution generator. It will be shown that they are likely to have good cryptographic performance from the list above.

The studies performed so far [3] have indeed proved that the deterioration of the differential and linear parameters of the S-blocks used in the ciphers can be compen-

sated by the increase in the minimum number of activated S-blocks on their first cycles. In particular, the design of a cipher is proposed, whose cycle function is built using large-scale controlled S-blocks, called SL transforms, which allow activating almost all S-blocks of the second and subsequent cycles [3]. It is shown that due to this, the cipher and with random S-blocks becomes a random substitution on the differential and linear indices on the third cycle (128-bit Rijndael becomes a random substitution on the differential and linear indices on the fourth cycle [2]).

However, some experts object to the use of random S-blocks in ciphers; they believe that accidentally taken S-blocks will not guarantee high resistance to algebraic cryptanalysis methods, and therefore in the cryptographic literature the task of finding S-blocks with high cryptographic indicators are allocated in a separate direction for improving the ciphers. The question arises whether the indicators of algebraic immunity and algebraic degree of random S-blocks to the conditions for ensuring high rates of stability of modern ciphers? Is there a correlation between these indicators?

Some answers to our questions were found in the publication of the journal "Discrete Mathematics" [28]. From the article cited in this edition, A.A. Horodilov, dedicated to the presentation of Boolean properties and their relation to the methods of cryptanalysis, we want to highlight a few theorems (results), which are given below.

A mess about the non-linear functionality of functions. In the designations of robots [28] Theorem 6. Here you will go after number 3.

Theorem 3. (nonlinearity of the random function N_f). *There is a constant $c < 1$ such that for almost all Boolean functions f of n variables, the condition holds $N_f \geq 2^{n-1} - 2c\sqrt{n}2^{n/2-1}$.*

For example, for $n = 8$, $c < 0.7$ is obtained $N_f \geq 128 - 32$. The most probable nonlinearity of a random byte S block obtained in experiments is $128 - 34$.

It is known that the nonlinearity of an arbitrary balanced function is the case, finding specific functions with high nonlinearity is a nontrivial problem. Use some kind of time-bound very complex methods $N_f \leq 2^{n-1} - 2^{n/2-1} - 2$. For $n = 8$ it turns out $N_f \leq 118$, but it is noted in [28], as is often f constructing such functions (methods of Sebery, K. Nyberg and others [1]). Today, we are following the path of filtering (selecting) random S-blocks using sufficiently large computing resources.

Our position is to find out that we want to realize realizable boundary values of the linear (that differentiation) levels of the LAT table, and also the XOR table does not require (recall that nonlinearity is uniquely related to the maximum offset value of the LAT table). Numerous experiments have shown that when stocked among the activated S-blocks in the first cycles, you can use randomly generated S-blocks in ciphers, even without checking their properties. A non-trivial task becomes trivial. As for other indicators of the main group of criteria, they remain at an acceptable level for random S-blocks, judging by the results of experiments. As for the other indicators of the main group of criteria, they remain at an acceptable level according to the results of the experiments for random S-blocks.

Let us focus, for example, on indicators of algebraic immunity of chance S-blocks. The cited work provides such well-known facts.

It is noted that the algebraic degree $\deg f$ is a natural upper bound for the algebraic immunity of the AI Boolean function f . In addition, the following upper bound of algebraic immunity depends on the number of variables n of the Boolean function. This is Theorem 11 in [28]. Here she will go to number 4.

Theorem 4. (top estimate for AI). *For an arbitrary Boolean function f from n variables, the condition $\text{AI}(f) \leq \lceil n/2 \rceil$, where $\lceil k \rceil$ – is an integer part of the number k is satisfied.*

It is known that this estimate is achievable. For $n = 8$, $\text{AI}(f) \leq 4$ is obtained.

Although there are examples of functions with maximum algebraic immunity, it is known that this class of functions is very small. However, an interesting fact is that the algebraic immunity of arbitrary (random) function is quite high.

We also give Theorem 13 from [28]. Here she will go to number 5.

Theorem 5. (AI of a random function). *For any $\alpha < 1$ and for almost all Boolean functions of n variables, the condition is satisfied $\text{AI}(f) > n/2 - \sqrt{n/2 \cdot \ln(n/(2\alpha \ln 2))}$.*

For $n = 8$, $\alpha = 0.7$, $\text{AI}(f) > 4 - 2,9 = 1,1$ is obtained.

Theorem 14 of [28] gives a known exact lower estimate of the nonlinearity of a function due to its algebraic immunity. Here she will go to number 6.

Theorem 6. (link AI and N_f). *The Boolean function f of n variables is a fair estimate.*

$$N_f \geq 2 \sum_{i=1}^{\text{AI}(f)-2} C_{n-1}^i.$$

For $n = 8$, it turns out $N_f \geq 58$.

Unfortunately, the results appear to be very blurred, but we could not find anything more specific.

In [28], a very important conclusion is drawn for us: the theoretical results show that in a *random Boolean function, most cryptographic parameters are close to optimal ones.*

6. Experiments

Above it is established that the distribution of even differences of random substitutions obeys Poisson law, and the displacements of the linear approximation tables are normal. Here are the results of the estimation of the randomness indices of the byte S-blocks from the output of the random permutation generator obtained by calculation and experimentally.

Table 1 shows the distribution of maximum values for the 256 bit substitutions calculated using the theoretical law of the distribution of the values of the XOR maxima of the sampling differences obtained in our work [3], and the results of the experiment.

Table 1. The distribution of the values of the maximums of the sample XOR differences of the substitutions of degree 2^8 obtained by calculation and experimentally

$k^* (X_1, X_2)$	$Pr(k^*)$	Estimated value Experiment	Estimated value Experiment
8	0,00004	0,01	0
10 (10,8)	$0,368 - 0,00004 = 0,368$	94	92
12 (12,10)	$0,905 - 0,368 = 0,537$	137	147
14 (14, 12)	$0,9901 - 0,905 = 0,008$	22	14
16 (16,14)	$0,9967 - 0,9901 = 0,0066$	1,71	3
18 (18,16)	$0,9999 - 0,9967 = 0,0032$	0,819	0

From the presented results it follows that theoretical and experimental results practically repeat each other. This means that for the distribution of differentials of byte substitutions the Poisson probability distribution law, which was used in constructing the integral law of distribution of maxima for these substitutions, is indeed fulfilled.

Table 2, also borrowed from our work [3], presents the law of the distribution of the values of the maximum displacements for the plurality of byte substitutions obtained by calculation and experimentally.

It can be seen that in this case the results of the experiments practically repeat the results of the calculations. Note here that experiments in both the first and the second case were performed on substitutions taken from the output of the random permutation generator without any filtering.

Therefore, it can be assured that the values of the XOR maxima of the differences for the differential byte substitution tables are in most cases 8-10, and the values of the displacements maximums of the linear approximation tables are 32-34.

Moreover, according to the results of the substitution results with XOR maxima, differences of less than 12 are 99% (less than 10 are 93%).

Table 2. The distribution of values of the maximums of displacements for the set of byte substitutions, calculated 2^8 obtained by calculation and by experiment

$k^* (X_1, X_2)$	$Pr(k^*)$	Estimated value	Experiment
26	$3,41 \cdot 10^{-7}$	0	0
28 (28,26)	$5,6 \cdot 10^{-4} - 3,4110^{-7} = 5,6 \cdot 10^{-4}$	0,14	0
30 (30,28)	$0,064 - 5,6 \cdot 10^{-4} = 0,0638$	16,3328	10
32 (32,30)	$0,368 - 0,064 = 0,304$	77,824	86
34 (34,32)	$0,692 - 0,304 = 0,388$	99,328	98
36 (36,34)	$0,874 - 0,692 = 0,181$	46,336	46
38(38,36)	$0,9518 - 0,874 = 0,078$	19,968	10
40 (40,38)	$0,9821 - 0,9518 = 0,03$	7,68	6
42 (42,40)	$0,9933 - 0,9821 = 0,011$	2,816	0
44 (44,42)	$0,9975 - 0,9973 = 0,00028$	0,07	0

In most cases, the offset maximums for linear tables of byte substitutions are 32-34. From the presented results, it follows that substitutions with a maximum displacement value of less than 36 are 94% (less than 34 are 76%).

Finally, it will be appropriate to give the results of experiments with random byte S-blocks obtained in [27], which are shown in Table 3 (with notations from this work).

Table 3. Cryptographic properties of randomly generated byte

Criterion	The value of	% generated S-blocks
Maximum DDT	8	0,004
Max Lat (Nonlinearity)	32(96)	11 (34)
	30(98)	0,15 (0,04)
	28(100)	0 (0,05).
The minimum degree of BF	7	30
Algebraic immunity	3	100

10 million random substitutions were generated. The table in brackets also shows our experimental results, but not for all criteria. We are particularly pleased with the indicators of algebraic immunity. According to our data, the S-block of the AES cipher has algebraic immunity 2.

However, there were experts who expressed doubts about the values of algebraic immunity.

Therefore, we developed our own program for calculating algebraic immunity [29]. The results obtained with its help, fully confirmed that all 100% accidental S-blocks have algebraic immunity equal to 3.

7. Discussion

The results of the studies confirmed that the substitutions from the output of the random permutation generator are likely to be good S-blocks. But given the still little experience of using random substitutions to build ciphers and being quite critical of this model for some specialists, it is suggested that an advanced random substitution model be considered as a random substitution from the output of a random substitution generator, which passes a positive check for compliance with at least four indicators

S-block and Boolean functions that form it:

1. The maximum value of the XOR junction is in the range of 8-10;
2. The maximum value of the displacement of the LAT is in the range 32-34 (i.e. the nonlinearity is 94-96);
3. The algebraic degree of Boolean functions of the S-block is not less than 7;
4. Algebraic immunity index of S-block is not less than 3.

It is a random substitution obtained without restriction, very likely to be suitable from the point of view of cryptographic applications. They have provided the best dynamic output of ciphers with strong linear transformations (which use at least one cycle function with controlled substitutions) to asymptotic indices of random substitutions. The cipher of such construction, which allows to increase the minimum number of activated S-blocks of the second cycle almost to the maximum, is offered in [3].

Thus, the scientific novelty of the work is seen in the fact that for the first time the possibility of using S-blocks for the construction of ciphers from the output of the random substitution generator is substantiated.

8. Conclusions

There is a long way to go about justifying the criteria for the selection of random substitutions from the simplest combinatorial to sufficiently rigid additionally developed criteria, which are built on the use of estimates of the closeness of laws of distribution of XOR tables and displacements of tables of linear approximations to theoretical laws.

However, it was not possible to find any particular advantages of substitutions selected using even rigid criteria. By their cryptographic index, which are determined by known methods, including algebraic, they are not particularly distinguished against the background of other known structures. Therefore, all considered criteria for the selection of random substitutions in the considered version had to be abandoned. We have moved to a more refined mathematical model of random permutation based on the properties of a sample of random substitutions (this model incorporates and found the differential and linear laws of the distribution of transitions of the corresponding substitution tables and the corresponding laws of the distribution of maxima).

At the same time, we recognize that permutations are one of the important elements in the designs of modern encryption transformations, playing the role of an additional, if not the main, and mechanism for effective random mixing of data blocks.

The main result of the work is a refined model of random substitution. According to this model, a substitution is considered random if it belongs to an ensemble of substitutions whose maxima of XOR tables and offsets of linear approximation tables obey the law of distribution of Fisher-Tippet extreme values (log-Weibul). This allows random (byte) substitutions in ciphers to be used directly by substitutions formed by a random permutation generator.

The refinement concerns the use of additional selection criteria which, as it turned out, do not substantially limit the many substitutions formed by the random generator.

An important conclusion is that for a random Boolean function, most of its cryptographic parameters are close to optimal. It will be natural this conclusion to random S-blocks: for a randomly-taken S-block, most of its cryptographic parameters are close to optimal.

As a result, the problem of constructing ciphers in which random S-blocks can be used without loss of stamina becomes relevant, which found its first solution in our work [3] and in several others.

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Impact of the Environmental Externalities and Technological Progress on the Stability of Economic System Development on the Example of the Ingulets River Basin

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Abstract. Our study demonstrates the introduction of a market-based mechanism for environmental management in conditions of a shortage of natural (water) resources. The purpose of this paper is to investigate the impact of environmental externalities and technological progress on the stability of economic system development. We considered a model of upstream and downstream firms with production negative externality, taking into account that producer pollutant and farm enterprise are situated along the Ingulets river. Experimental data and OLS method were used in this model. The results of the study and practical recommendations will allow participants of the technological process to respond quickly to changes in the state of the environment and make effective decisions aimed at ensuring the stability of the economic system and environmental safety. We found that enterprise's rate of technological development inspired by IT implementation has to be 0.28 times more than technological development of pollutant to save the stability of farm enterprise's output.

Keywords: IT progress, enterprise stability, IT capital, external environmental costs, wastewater discharges, water quality

1 Introduction

In modern conditions, a relatively new environmental function of the state has been formed and received its constitutional consolidation. It is aimed at harmonizing relations between society and nature [1]. The implementation of this function of the state is carried out through regulation of the ratio of environmental and economic interests of society with the mandatory priority of the human right to a safe environment for life and health. This is carried out through the management of natural resources and environmental protection.

Externality means that results of one agent (individual or firm) depends on factors or actions that are not under his own control but are decided by other agents or nature

(“polluters”) in general equilibrium theory which is connected with sustainable economic systems.

Unsustainability means lack of long run environmental equilibrium of economic system. Consequences of disequilibrium is characterized by decreasing stocks of exhaustible resources, increasing pollution’s concentrations, loss of biodiversity.

Broadly speaking, sustainability does not require absence of positive or negative externalities at all. Reducing one type of externality usually generates another. Joint resource for different economic agents is a reason of negative dynamic externality. “Transition from the current unsustainable system to a sustainable one is prevented by the lock-in of certain technologies, so government policy is needed” [2].

Instruments of sustainability policy includes natural capital depreciation tax which stimulate change from non-renewable resources to renewable ones; “precautionary polluter pays principle”.

The **goal** of the paper is to analyze an impact of the environmental externalities and technological progress on the stability of economic system development on the example of the Ingulets River Basin.

The paper has the following structure: section 2 is devoted to the related works; section 3 describes mathematical approach of externalities and sustainability economics; section 4 reveals the practical implementation of the environmental management system in the Ingulets River Basin; section 5 introduces model of upstream and downstream firms with negative externality and IT capital; section 6 analyses impact of the environmental externalities and technological progress on the stability of economic system development using experimental data; the final section concludes.

2 Related works

In our study [3] the issue of the impact of economic activity on the environment has already been considered. Thus, the influence of economic activity on the fish population during sand mining was previously described. It has been shown that internal mining can be carried out without creating adverse effects on the water body provided the extraction to be carried out within the limited optimal amount of sand extraction established by local authorities. To determine the ecological balance in the hydroecosystem during the extraction of sand, the mathematical model was proposed. However, the balance may not always be achievable. And then it becomes necessary to restore natural resources, which should be carried out at the expense of the environmental pollutant.

The authors in [4] considered a quantification of air pollution externalities from electricity production. It was shown that command-and-control measures are more effective than market tools under internalizing of external expenses in CEE countries. This research of the internalization of external costs deals only with airborne pollution, while energy production can also be trigger of other types of negative externalities, which require further research.

The problem of comparing the impact of electricity production technologies and

fuels on the environment due to their differences is quite complex. The appropriate way of analysis today is the external cost approach, by which “a monetary value is associated with environmental damage” and “damage to human health caused by the annual operation of Croatian thermal power plants” were calculated [5].

Since the goal of energy policy is to promote environmentally optimal solutions, in Italy to compare the potential environmental impacts of alternative policy is applied to quantify the impact of atmospheric emissions; so biogas support schemes in Italy were considered and revised to include subsidies for biomethane production process [6]. “Agriculture also has a significant effect on the environment and human health” [7]. In the paper were calculated the external costs of agricultural production in the USA taking into account natural resources, ecosystem biodiversity and human health. The existence of such costs is a reason to transform agricultural policy, which can shift technology that reduce external influences.

In the UK has been established that significant external costs arise due to contamination of drinking water with pesticides, nitrates, cryptosporidium and phosphates because of damage to wildlife, habitats, hedgerows, from gas emissions, soil erosion and organic carbon losses etc [8]. This research estimate such external effects that lead to financial costs, and therefore probably underestimate the overall negative impact of agriculture industry. This involves redirecting government subsidies to stimulate those positive externalities that are underrepresented on the market.

According to the simulation results [9], global warming will make up “from 10% to 40% of all external costs in the 21st century; the internalization of the external cost will cause a decline in economic growth by approximately 5%, whereas forest preservation will increase by 40% and fossil-fuel consumption will be reduced by 15%”.

3 Externality versus sustainability economics: mathematical approach

Dynamic general equilibrium model can assess the impacts of environmental pollution on production function for enterprises of different industries.

Cost of enterprises which save environment (TC) is more than TC_{ne} of non-environmental friendly enterprises: $TC > TC_{ne}$. Social welfare for individuals, firms and state authority is the difference between reservation price U and total costs, plus externalities: $W = U - TC - TC_{ne} + E$ [10].

Industry externalities result when agglomeration occurs within an IT industry or sector (i) due to specialization or localization effects, (ii) among firms in different industries of sectors that are located in close proximity due to diversity or urbanization economies. Some authors [11] in Green Solow Model consider each economic activity as technology, $F(K; L)$, which generates pollution. Aforementioned model is suitable to describe long run effects of pollution, but they do not capture short-run effect of pollution in contrast of discrete time models:

$$g(k) = Ck^\rho(E - k)^\omega,$$

where $C > 0$ is a constant, $\rho > 0$ is the capital elasticity, $E > 0$ is the state of

environment if production activity is absent and $\omega > 0$ is pollution effect.

The model introduced production function, in which the environmental resource is the stock of natural resource involved in the productive process with positive constants:

$$Y_t = F(K_t, L_t, E_t) = K_t^\alpha L_t^\beta E_t^\gamma.$$

According to [12], there are 3 main sources of pollution, which can have influence on economic systems: byproduct of consumption, pollution as input and pollution as externality. Traditionally a parameter measuring the pollution intensity of output was considered as exogenous, but in modern models [12] pollution was explored as endogenous variable.

Pollution $P(t)$ arises as an externality of technology of the production function of the inputs:

$$P(t) = Q^{-\xi}(t) \sum_{j=1}^N X_j^t,$$

where $\xi \in (-1; 1)$ is a constant estimating the effect of technological production $Q(t)$ on pollution $P(t)$. Consequently the more ξ the low pollution and vice versa.

Sustainable resource use and economic dynamics can be described by Cobb-Douglas technology [13, 14]:

$$Y = AK^\alpha L^\beta R^{1-\alpha-\beta}$$

where A is technology, K and L are capital and labor correspondingly, input R is a pollution.

$$\frac{Y}{K} = A \left(\frac{L}{K}\right)^\beta \left(\frac{R}{K}\right)^{1-\alpha-\beta}$$

$$\frac{R}{Y} = A^{-\frac{1}{1-\alpha-\beta}} \left(\frac{Y}{L}\right)^{\frac{\beta}{1-\alpha-\beta}} \left(\frac{Y}{K}\right)^{\frac{\alpha}{1-\alpha-\beta}}$$

Capital productivity increases with pollution. Capital is a clean substitute for polluting inputs in production. Technological change decreases the pollution intensity: the less resources the less pollution level for unchangeable output.

4 The practical implementation of the environmental management system in the Ingulets River Basin

In our research, we present an example of the environmental management (internalization of external environmental costs) system model, implemented in the Ingulets River basin. A subject of management is Interdepartmental Commission of the State Agency for Water Resources of Ukraine. It carries out governing influence on the management object – mining enterprises Kryvbas. The management object based on a regulatory document “The regulation for channel flushing and ecological rehabilitation of the Ingulets River, improvement of water quality in the Karachunivske Reservoir and at the water intake of the Ingulets irrigation system” regulates its influence on the formation of quantitative and qualitative indicators of the aquatic environment of the Ingulets River).

In the Kryvyi Rih basin, 8 of 11 Ukrainian enterprises for the extraction and processing of iron ore are located. Here are enterprises serving the metallurgical

industry – one of the world's largest metallurgical plants (PJSC “ArcelorMittal Kryvyi Rih”), five mining and processing combines (MPC) – Pivnichnyi MPC (PivnMPC), Pivdennyi MPC (PivdMPC), Tsentralnyi MPC (TMPC), Novokryvorizky MPC (NKMP), Inhuletskyi MPC (InMPC), three ore repair plants [15]. As a result of iron ore mining in Kryvyi Rih, a huge volume of highly mineralized mine water is being formed, which are discharged into the Ingulets River. Mineralization of mine water very often exceeds the salinity of sea water [16]. Wastewater discharge in the Ingulets River leads to a deterioration in water quality downstream from the city of Kryvyi Rih. At the same time water of the Lower Section of the Ingulets River is taken for irrigation [15-17].

The south of Ukraine is characterized by an insufficient amount and uneven distribution of precipitation with frequent droughts and dry winds, which affects the normal development of crops. Such conditions cause sharp fluctuations in harvest over the years and cause instability of agricultural production. Therefore, the Mykolaiv region is considered as a zone of risky agriculture, where irrigation is urgently needed. Irrigation is carried out by the waters of the Ingulets River. Water enters the main canal through two pressure pipelines with a diameter of 2.8 m and a length of 600 m. The main canal and the entire irrigation network are built in the earthen channel. It consists of 11 first-order inter-farm distributors and 14 lower-order distributors with a total length of more than 410 km.

The total area of irrigated land in the Mykolaiv region is 190.3 thousand hectares. Irrigated lands are located in 19 districts of the region. The reclamation complex of the region includes 22 inter-farm irrigation systems. Water from the Ingulets River flows into systems:

1. Yavkynska IS (Snihurivskiyi, Zhovtnevyi, Berezhnevatskiy, Bashtanskiy areas) was commissioned in 1977, the source of the water intake of the Ingulets River, the irrigation area – 50.3 thousand hectares, the length of the main and distribution channels – 107.4 km;

2. Ingulets IS (Snihurivskiyi, Zhovtnevyi areas) was commissioned in 1963, the source of the water intake of the Ingulets River, irrigation area – 42.7 thousand hectares, length of main and distribution channels – 461.2 km (Fig. 1).

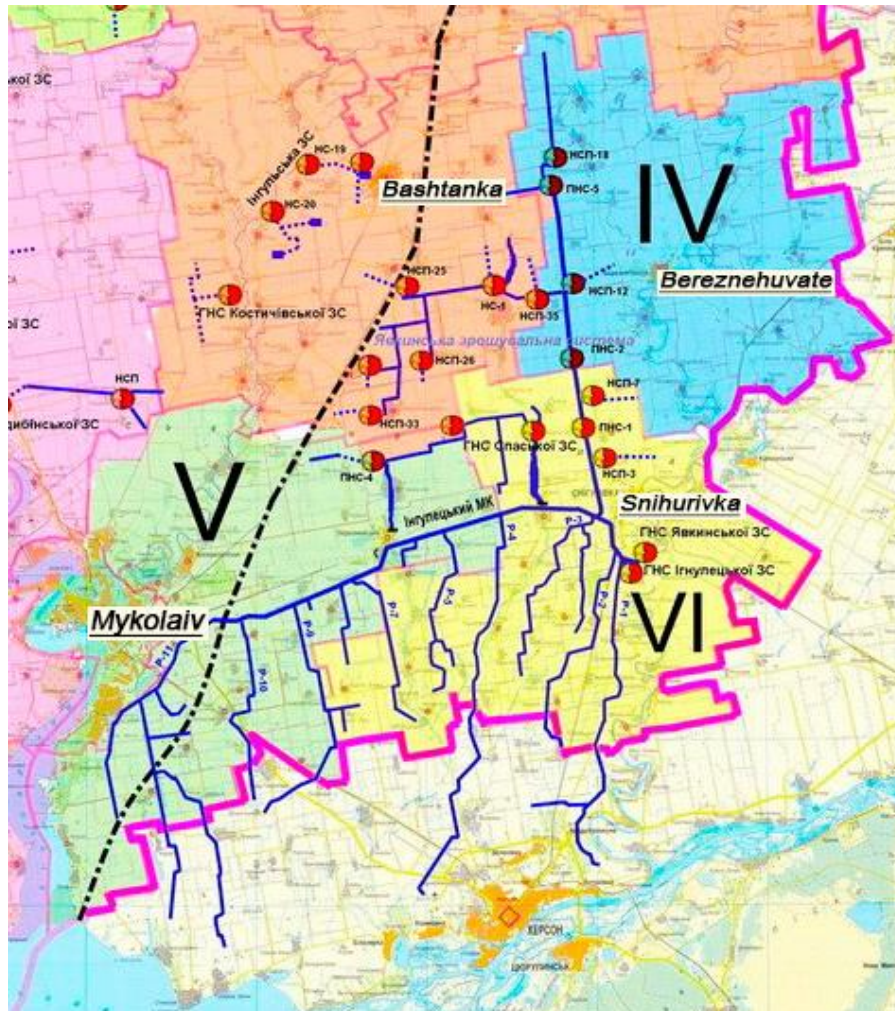


Fig. 1. Water management and reclamation complex of the Mykolaiv region

Irrigation is also possible if the river water quality is controlled and complies with the irrigation standards. Therefore, the Interdepartmental Commission of the State Agency for Water Resources of Ukraine annually approves “The regulation for channel flushing and ecological rehabilitation of the Ingulets River, improvement of water quality in the Karachunivske Reservoir and in the water intake of the Ingulets irrigation system” [18]. The Commission analyzes the hydrometeorological situation in the Ingulets River Basin, information on water quality in the Karachunivske Reservoir, into which wastewater from Kryvbas enterprises is discharged, and from which water enters the Ingulets River.). The Commission adopts a Regulation specifying what compensation volume of water should be added into the reservoir at the expense of the Dnieper-Ingulets channel for dilution of highly mineralized waters and improvement

of water quality. It also obliges the mining enterprises that discharged the wastewater to pay for the environmental improvement of the Ingulets River.

The total volume of discharge from the Karachunivske Reservoir is about 120.0 million m³; under the agreement 105 million m³ are paid by the mining enterprises of Kryvbas and 15.0 million m³ are paid by the state budget [18]. Thus, before the start of the irrigation season, there is a gradual increase of discharges from the Karachunivske Reservoir, which is then regulated to ensure the necessary volumes and quality of water of the Lower Section of the Ingulets River in accordance with irrigation standards. And agrarian farms of the Mykolaiv region can use river water for irrigation.

Calculations for flushing of the Ingulets River and bringing the water quality indicators into the Ingulets River at the level of the Main Pumping Station of the Ingulets Irrigation System (MPS IIS) should be based on the chlorine ions ratio in the Dnieper-Ingulets supply channel, since this ion is inert and does not go into any reactions. Volumes of Dnieper water should be calculated in such a way that at the level of MPS IIS (town Snihurivka) mixed waters of Dnieper and Ingulets correspond to the standards of SSTU 2730: 2015 “Quality of natural water for irrigation. Agronomic criteria” for irrigation water of the first class. Water management situation in the Ingulets River Basin for the upper (Andriivka) and lower (Snihurivka) course of river for the 2019 observation period is explained in Table 1 [19].

Table 1. Water management situation in the Ingulets River Basin for the observation period 2019

Water sampling site	Date	The volume of supplied water by the Dnieper-Ingulets canal, thousand m ³	Discharge from the Karachunivske Reservoir, thousand m ³	Chlorides (MPC=350 mg/dm ³)
				actual, mg/dm ³
Andriivka	21.01	–	–	1680
Snihurivka				1660
Andriivka	19.02	–	–	3120
Snihurivka				1900
Andriivka	12.03	–	–	980
Snihurivka				2250
Andriivka	16.04	7603,0	23778,0	220
Snihurivka				400
Andriivka	07.05	27779,0	51928,2	340
Snihurivka				280

Andriivka	18.06	64425,0	91845,0	360
Snihurivka				340
Andriivka	16.07	93623,0	118456,2	420
Snihurivka				330
Andriivka	13.08	–	–	400
Snihurivka				420
Andriivka	17.09	–	–	1800
Snihurivka				480
Andriivka	15.10	–	–	2100
Snihurivka				550
Andriivka	19.11	–	–	1380
Snihurivka				1400
Andriivka	17.12	–	–	1680
Snihurivka				1400

At the beginning of the irrigation season of 2019, the irrigated area was 190 thousand 321.8 hectares in the Mykolaiv region [20]. 16 water samples at 16 observation points were taken for chemical analysis to determine the water quality of irrigation sources. The chemical analysis of water samples was carried out in the laboratory of the Pivdenno-Buzke Basin Department of Water Resources. The determination of water quality was carried out in accordance with the state standard of Ukraine SSTU 2730: 2015 “Quality of natural water for irrigation. Agronomic criteria“.

Water sampling results for the observation period 2019 are explained in Table 2.

Table 2. Water quality in the Ingulets IS for the observation period 2019

Ingredient	2019 year		
	start of irrigation season 19-21.03	mean for irrigation period 15.04-15.08	end of irrigation season 18-19.09
Mineralization, mg/dm ³	5673	621	1903
Chlorides, mg/dm ³	2821,82	354,00	482,12
Sulphates, mg/dm ³	666,18	499,16	619,15
pH	8,3	7,2	7,7

Chemical composition	sulfate-chloride, magnesium-sodium	sulfate-chloride	hydrocarbonate-sulfate-chloride, calcium-magnesium-sodium
Water quality characteristic	III class unsuitable for irrigation	I class suitable for irrigation	III class unsuitable for irrigation

So, after washing the channel and improving the Ingulets River irrigation water corresponds to the first class of quality (suitable for irrigation without restrictions) and can be used by agricultural enterprises for irrigation of agricultural land. The high mineralization and chloride content at the beginning and at the end of the irrigation period are explained by the fact that at the time of water sampling, the irrigation season had not yet begun (it had already ended), and the Dnieper-Ingulets canal water supply to the headwater of the Ingulets River, which aims at diluting the river water in order to reach safe for watering criteria, has not yet (already) been carried out.

The content of toxic salts in the mixed waters of the Ingulets main canal on average during the irrigation period is about 420-490 mg/dm³ with a deviation to 70-140 mg/dm³ in both directions. That is, the composition is determined by the volume of Dnieper water supplied to the headwater of the Ingulets River to dilute the Ingulets water to criteria that are safe for irrigation. The main polluting factor remains the discharge of mine water in the upper course of the Ingulets River from enterprises of Kryvbas.

Thus, the enterprises of Kryvbas, along with other production costs, include environmental costs in the total (internal). That is, the costs that ensure the elimination of environmental (water) pollution are external for polluting enterprises, since for the metallurgical and mining enterprises, the damage caused by their activities does not affect production costs. In this case, external costs are manifested in an increase in the costs of industrial, rather than agricultural, enterprises for the subsequent treatment of polluted water of the Ingulets River.

Of course, such a scheme provides an opportunity for agricultural holdings, which are located downstream of the Ingulets River, to use water for irrigation. However, the annual flushing of the Ingulets River by feeding Dnieper water through the Dnieper-Ingulets canal, does not lead to self-regulation of the chemical composition of the water and the possibility of using the river for fishing purposes [17]. The development of environmental measures is recommended, primarily aimed at reducing the volume of wastewater in the source of their formation (at the enterprises of Kryvbas), as well as the introduction of closed water production cycles, which will positively affect the resumption of the ability of the aquatic ecosystem to self-regulation and self-purification).

5 Model of upstream and downstream firms with negative externality and production function with IT capital

IT capital into a production function of firm include personal computers, servers, storage capacity and nodes for information workflow. These factors have effects on production function and cost efficiency.

There is a positive effect of IT capital (i.e., intangibles as well as the tangible assets, such as computer hardware and software) on productivity of firms. ICT “allows companies to perform activities in a faster, more accurate, and more flexible manner” [21]. ICT as a rule includes innovations. Improved production function due to innovations includes “significant changes in techniques, equipment, or software” [21].

ICT can enter into a production function equation as exogenous variable. Use of ICT allow introducing processes, which can reason of higher productivity and lower average cost in firms. Thus ICT has direct (IT capital) and indirect impact (product innovations and business process innovations) on production technology of a firm. A change in production technology causes a change in average cost (Fig. 2) [22].

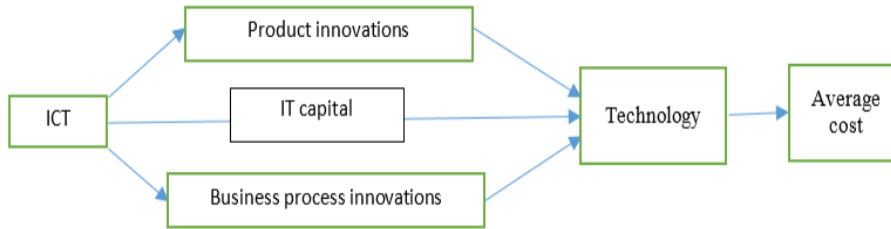


Fig. 2. Direct and indirect impact of ICT on technology of production function

Let's consider production negative externality for producer pollutant (public corporation ArcelorMittal, Kryvyi Rih, Ukraine) and farm enterprise situated along the Ingulets River. The upstream firm (pollutant) x has a production function of the form:

$$x = e^{h_x t} k^{\alpha_1} l^{\beta_1}, \quad (1)$$

where k is the number of machine hours per day, l is the number of labor hours per day [23], h is the rate of technological development during period t due to implementation of information technology. The downstream firm y has own production function and its output may be affected by the chemicals firm x into the river:

$$y = e^{h_y t} k^{\alpha} l^{\beta} (x - x_0)^{-|\gamma|} \quad (2)$$

where x_0 demonstrates the river's natural capacity for pollutants. If $\gamma = 0$, x 's production process has no effect on firm y , whereas if $\gamma < 0$, increase in x above x_0 causes y 's output to decline.

Total cost of downstream firm y is

$$TC(y) = r \cdot k + w \cdot l \quad (3)$$

where r is rate of capital per hour, w is wage per hour. Express l from equation (2):

$$l = e^{-\frac{h_y}{\beta}t} k^{-\frac{\alpha}{\beta}} (x - x_0)^{-\frac{|\gamma|}{\beta}} y^{\frac{1}{\beta}} \quad (4)$$

After substitution (4) in (3) we obtain:

$$TC(y) = r \cdot k + w \cdot e^{-\frac{h_y}{\beta}t} k^{-\frac{\alpha}{\beta}} (x - x_0)^{-\frac{|\gamma|}{\beta}} y^{\frac{1}{\beta}}. \quad (5)$$

To get equilibrium capital hours, calculate FOC $\frac{\partial TC(y)}{\partial y} = 0$:

$$\frac{\partial TC(y)}{\partial y} = r + w \cdot e^{-\frac{h_y}{\beta}t} \left(-\frac{\alpha}{\beta}\right) k^{-\frac{\alpha}{\beta}-1} (x - x_0)^{-\frac{|\gamma|}{\beta}} y^{\frac{1}{\beta}-1} = 0.$$

From the last equation we can formulate k as following function:

$$k = \left(\frac{w}{r}\right)^{\frac{\beta}{\alpha+\beta}} \cdot \left(\frac{\alpha}{\beta}\right)^{\frac{\beta}{\alpha+\beta}} \cdot e^{-\frac{h_y}{\beta}t} (x - x_0)^{\frac{|\gamma|}{\alpha+\beta}} y^{\frac{1}{\alpha+\beta}}. \quad (6)$$

Using substitution (6) to (5) we have:

$$TC(y) = (w^{\beta} r^{\alpha}) \cdot \left[\left(\frac{\alpha}{\beta}\right)^{\frac{\beta}{\alpha+\beta}} + \left(\frac{\beta}{\alpha}\right)^{\frac{\alpha}{\alpha+\beta}} \right] \cdot e^{-\frac{h_y}{\alpha+\beta}t} \cdot (x - x_0)^{\frac{|\gamma|}{\alpha+\beta}} y^{\frac{1}{\alpha+\beta}}. \quad (7)$$

where $e^{-\frac{h_y}{\alpha+\beta}t}$ is impact of IT during each year t (decrease of total cost of farm enterprise for same output), $-\frac{|\gamma|}{\alpha+\beta}$ is impact of negative externality of producer pollutant.

Using the same transformation we can obtain total cost of pollutant:

$$TC(x) = (w^{\beta_1} r^{\alpha_1}) \cdot \left[\left(\frac{\alpha_1}{\beta_1}\right)^{\frac{\beta_1}{\alpha_1+\beta_1}} + \left(\frac{\beta_1}{\alpha_1}\right)^{\frac{\alpha_1}{\alpha_1+\beta_1}} \right] \cdot e^{-\frac{h_x}{\alpha_1+\beta_1}t} \cdot x^{\frac{1}{\alpha_1+\beta_1}}. \quad (8)$$

Taking into account production function (1) we can rewrite $TC(y)$ as

$$TC(y) = (w^{\beta} r^{\alpha}) \cdot \left[\left(\frac{\alpha}{\beta}\right)^{\frac{\beta}{\alpha+\beta}} + \left(\frac{\beta}{\alpha}\right)^{\frac{\alpha}{\alpha+\beta}} \right] \cdot e^{-\frac{h_y}{\alpha+\beta}t} \cdot (e^{h_x t} k^{\alpha_1} l^{\beta_1} - x_0)^{\frac{|\gamma|}{\alpha+\beta}} y^{\frac{1}{\alpha+\beta}}. \quad (9)$$

Total cost will change over time as follows $\frac{\partial TC(y)}{\partial t}$ and will be equivalent to the following expression: $\frac{1}{\alpha+\beta} \cdot \left[-h_y + \frac{|\gamma| \cdot h_x \cdot x}{x - x_0}\right]$. If $x_0 = 0$, then total cost of downstream firm will decrease if and only if $-h_y + |\gamma| \cdot h_x < 0$. It means that $\frac{h_y}{h_x} > |\gamma|$, i.e. stability of farm enterprise is reached then ratio of technological development of downstream and upstream firm has to be more than externality value $|\gamma|$.

6 Experiment

Using open data of ArcelorMittal (table 3), and linear transformation of Cobb-Douglas equation (1) we got new variables: $\ln x = A + \alpha_1 \ln l + \beta_1 \ln k$ (table 4).

Table 3. Production technology of ArcelorMittal

Year	Output x , hrn.	Labor l , hours	Capital k , hours
1	12767,5	375,2	131427
2	16347,1	402,5	134267
3	19542,7	478	139038
4	21075,9	553,4	146450
5	23052	616,7	153714
6	26128,2	695,7	164783
7	29563,7	790,3	176864
8	33376,6	816	188146
9	38354,3	848,8	205841
10	46868,3	873,1	221748
11	54308	999,2	239715

Table 4. Log transformation of production technology of ArcelorMittal

Year	$\ln(x)$	$\ln(l)$	$\ln(k)$
1	9,45	5,93	11,79
2	9,70	6,00	11,81
3	9,88	6,17	11,84
4	9,96	6,32	11,89
5	10,05	6,42	11,94
6	10,17	6,54	12,01
7	10,29	6,67	12,08
8	10,42	6,70	12,14
9	10,55	6,74	12,23
10	10,76	6,77	12,31
11	10,90	6,91	12,39

Using OLS method we have $\ln(x) = -9.68 + 0.46 \cdot \ln(l) + 1.4 \cdot \ln(k)$ ($R^2 = 0.98$) or $x = 6.28 \cdot 10^{-5} k^{1.4} l^{0.46}$.

Using open data of farm enterprise (table 4), output of pollutant (table 3) and linear transformation of Cobb-Douglas equation (2) we obtain new variables $\ln(y) = B + \alpha \cdot \ln(l) + \beta \cdot \ln(k) + \gamma \cdot \ln(x)$.

Table 5. Production technology of farm enterprise

Year	Output y , hrn.	Labor l , hours	Capital k , hours	Output x , hrn.	$\ln(y)$	$\ln(l)$	$\ln(k)$	$\ln(x)$
1	78360	128245	43	12767,5	11,27	11,76	3,76	9,45
2	15007	20774	30	16347,1	9,62	9,94	3,40	9,70
3	27802	77211	35	19542,7	10,23	11,25	3,56	9,88
4	21458	21444	71	21075,9	9,97	9,97	4,26	9,96
5	6242	7836	93	23052	8,74	8,97	4,53	10,05
6	33855	31514	142	26128,2	10,43	10,36	4,96	10,17
7	3162	6728	18	29563,7	8,06	8,81	2,89	10,29
8	20006	23967	183	33376,6	9,90	10,08	5,21	10,42

9	8007	5649	33	38354,3	8,99	8,64	3,50	10,55
10	18389	33494	87	46868,3	9,82	10,42	4,47	10,76

Similarly using OLS method we have $\ln(y) = 4.02 + 0.73 \cdot \ln(k) + 0.31 \cdot \ln(k) - 0.28 \cdot \ln(x)$ ($R^2 = 0.89$) or $y = 55.57 \cdot k^{0.73} \cdot l^{0.31} \cdot x^{-0.28}$.

Each 1% increasing of pollutant stocks will decrease on 0.28% of farm enterprise's output. Thus farm enterprise's rate of technological development inspired by IT implementation has to be 0.28 times more than technological development of pollutant to save the stability of its output.

7 Conclusions

Our study investigated the impact of environmental externalities and technological progress on the stability of economic system development using market-based mechanism for environmental management in conditions of a shortage of natural (water) resources. We considered a model of upstream (pollutant) and downstream (farm enterprise) firms with production negative externality, taking into account that producer pollutant and farm enterprise are situated along Ingulets river. The results of the study and practical recommendations will allow participants of the technological process to respond quickly to changes in the state of the environment and make effective decisions aimed at ensuring the stability of the economic system and environmental safety.

We found that stability of farm enterprise is reached then ratio of technological development of downstream and upstream firm has to be more than externality value. For our data we reveal that each 1% increasing of pollutant stocks of ArcelorMittal will decrease on 0.28% of farm enterprise's output along the Ingulets river basin. Thus, farm enterprise's rate of technological development inspired by IT implementation has to be 0.28 times more than technological development of pollutant to save the stability of its output.

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A hybrid approach for feature selection in data mining modeling of credit scoring

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Abstract. Recent year researches shows that data mining techniques can be implemented in broad areas of the economy and, in particular, in the banking sector. One of the most burning issues banks face is the problem of non-repayment of loans by the population that related to credit scoring problem. The main goal of this paper is to show the importance of applying feature selection in data mining modeling of credit scoring. The study shows processes of data pre-processing, feature creation and feature selection that can be applicable in real-life business situations for binary classification problems by using nodes from IBM SPSS Modeler. Results have proved that application of hybrid model of feature selection, which allows to obtain the optimal number of features, conduces in credit scoring accuracy increase. Proposed hybrid model comparing to expert judgmental approach performs in harder explanation but shows better accuracy and flexibility of factors selection which is advantage in fast changing market.

Keywords: Credit Scoring Model, Feature Selection, Hybrid Approach, Data Mining, IBM SPSS Modeler

1 Introduction

Recent year researches shows that data mining techniques can be implemented in broad areas of the economy and, in particular, in the banking sector. Banks and other credit institutions have faced the need to process large amounts of data at a growing rate. The imperatives for the volume of data operations and the speed of their processing require these processes to be almost completely automated. These requirements apply not only to direct digitalization, but also to the procedures for developing appropriate mathematical models. Credit scoring models are a prime example. They are increasingly combined with new computational methods based on data mining.

An extremely important problem in scoring modeling was and remains the choice of the borrowers' characteristics, which are decisive in loan decision making. In terms of the model, these characteristics are often known as the explanatory variables, covariates, predictor attributes, predictor variables, independent variables or, typically, features. Set of the most influential features is not permanent. It changes over time and is significantly dependent on the macroeconomic situation and national specificities.

Researchers [16] analyzed 187 papers from 1992 to 2015 on credit scoring and noted that feature selection is the No.4 objective of seven types of main objectives: proposing a new method for rating, comparing traditional techniques, conceptual discussions, feature selection, literature review, performance measures studies and other issues. The authors of this research have set this objective for 95 articles, representing 51% of the total, with 52 articles published since 2011. Among the main studies of the 2002-2015 period, which are devoted to the feature selection, can be highlighted [2, 4, 6, 11, 14, 15, 18, 20, 22, 27, 28].

Relevant problems are also actively researched in the last four years. The examples of publications are as follows [2, 3, 8, 10, 17, 24-26]. The focus of pertinent researches on feature selection is increasingly being shifted toward machine learning and hybridization methods.

Nowadays software implementations of machine learning algorithms in credit scoring can take place using the following classes of software: business application packages (statistical packages and analytics platforms, such as SAS/STAT, SAS Enterprise Miner, IBM SPSS Modeler, STATISTICA Data Miner), open platforms (Python, R, Apache Spark) and cloud solutions (Microsoft Azure Machine Learning Studio, Google Machine Learning Engine).

Despite all the advantages of cloud-based data analytics, it is not widely used in banks due to security concerns about the passing confidential data to the cloud.

The biggest advantage of open environments is the ability to use much more algorithms comparing to business application packages. However, they impose additional qualification requirements for the developers of scoring models.

Therefore, statistical packages and analytical platforms are the most commonly used in banks. They include analytical pre-proceeding tools, ready and customizable machine learning algorithm templates. In addition, these packages allow to configure model settings and use interactive quality assessment techniques. This conclusion is also confirmed by the authors of the paper [26].

Business application packages have powerful functionality to solve the problem of feature selection, which can be improved by combining built-in approaches and hybridization.

That is why, it is extremely important to improve the functionality of these software products for developing scoring models in general, and for making feature selection in particular.

The purpose of this study is to propose new hybrid approaches to the feature selection, which will improve the quality of credit scoring models, built on intelligent data analysis, machine-learning approaches in today's analytics platforms.

2 Literature review

From last few decades more and more attention has been paid to the problem of credit scoring [21, 23]. Artificial Neural Networks (ANNs) [25] and Support Vector Machine (SVM) [4, 20] are two commonly soft computing methods used in credit scoring modelling. Other methods like evolutionary algorithms, stochastic optimization technique

have shown promising results in terms of prediction accuracy [26]. Besides, there are also traditional approaches based on expert knowledge which allow to develop expert judgmental models [7], scoring expert systems [1] and mixed models.

Feature selection algorithms, generally as preprocessing methods of scoring model creation, can be used to increase the classification performance. They have a number of benefits as follows [19]: decreasing the noise in dataset; reducing the computational cost in order to successfully acquire proper models; helping to better understand the final models in the classification algorithms; simple application; assisting in updating the model.

We have studied a lot of publications regarding the problem of credit scoring in data mining with applying feature selection techniques. Some of them are described below.

Starting with primitive approaches, use of expert judgmental forms is a good source for initial features list creation. It is not common for long existing credit business, however in case of new lending segments emergence under condition of data shortage it shows acceptable effectiveness.

One of the simplest and widespread statistical approach is ‘weight of evidence’ and ‘information value’ indicators use, explained by Siddiqi in [21].

Kuhn and Johnson describe in [12-13] two main types of feature selection techniques: wrapper and filter methods. The filter approach considers the feature selection process as a separate step of learning algorithms. The filter model uses evaluation functions to evaluate the classification performances of subsets of features. There are many evaluation functions such as feature importance, Gini, information gain, the ratio of information gain, etc. A disadvantage of this approach is that there is no relationship between the feature selection process and the performance of learning algorithms.

The wrapper approach uses a machine-learning algorithm to measure the set goodness of selected features. The measurement relies on the performance of the learning algorithm such as its accuracy, recall and precision values.

The papers [25-26] systemize a credit scoring model based on deep learning and feature selection to evaluate the applicant’s credit score from the applicant’s input features.

The objective of many studies is to analyze the outperform feature selection techniques among conventional and heuristic techniques in various applications [14, 17, 28].

A lot of researches embody the optimization approach to find the best subset of predictors for improving scoring model performance [3, 6, 27]. For instance, in [3] authors suggested to study local search, stochastic local search and variable neighborhood search for feature selection in credit scoring. The proposed feature selection is then combined with a support vector machine to classify the input data.

Publications of the recent years show for credit scoring problem active use of principal component analysis feature selection: PCA is a transformation process to reduce the number of features by extraction of the new independent features [7, 11, 25].

These days, there are more and more examples of the use of different hybrid feature selection techniques.

A hybrid approach in data mining models of feature selection algorithms and ensemble learning classifiers for credit scoring was used by Koutanaei, Sajedi and Khanbabaie [11]. Credit scoring modeling based on feature selection approach and parallel Random Forest were described by Ha Van Sang, Ha Nam and Nguyen Duc Nhan [8]. For feature selection, a feature clustering approach was proposed to find optimal set of predictors by authors [24]. Kamalov and Thabtah suggested a new filtering method that combines and normalizes the scores of three major feature selection methods: information gain, chi-squared statistic and inter-correlation [10]. Chornous and Nikolskyi prove that a great improvement can be reached by applying hybrid approach to feature selection process on additional variables (more descriptive ones that were built on initial features) for case with limited computational resources [5].

This study in comparison with others proposes a unique approach for feature selection techniques and has in advantage the accessibility of the approach for users of analytical platforms, business application packages, using the capabilities of the built-in tools and offering methods for combining them.

Scoring modelling techniques mentioned in studied works are commonly used, but their aim mostly to show an increase of models performance accuracy directly. Previous studies compare different approaches or miss the relationship between the feature selection process and the performance of learning algorithms. So the authors' aim is the search of techniques conjunction for features selection to reach and explain better models performance.

Besides, it is obvious that the usage of feature selection techniques differs among countries, so the results of this particular study can be implemented in real business cases in Ukraine.

Important tasks of this research are to show the advantages of modern powerful analytical platforms (on the example of IBM SPSS Modeler) for solving the problems of credit scoring in general and making the feature selection in particular; to suggest the concept of an effective combination of their tools; to show the experimental results of the joint application of options in Feature Select node and PCA/Factor node to optimize the feature selection process and to model credit scoring on the example of Ukrainian bank data.

3 Methodology

Dataset and tools

The dataset was collected and systematized all socio-economic information about them at the stages of loan repayment, collected information about the timeliness of the loan by Ukrainian bank during the stages of providing consumer loans to individuals.

The original dataset consists of 61 fields with a record volume of 61 216. It is advisable to use all the data in this database, not just a subset, which will allow us to build more accurate models. Non-relevant records or non-relevant attributes may not be included. The available data is in several formats: numeric, categorical and logical.

All the computing work was done in nodes from IBM SPSS Modeler. This software product has powerful functionality for solving binary classification tasks, including credit scoring.

To select important features, such built-in tools as the Feature Selection node and the PCA/Factor node are used [9].

The Feature Selection node allows to implement 3 key procedures:

1. Screening that removes unimportant and problematic inputs and records, or cases such as input fields with too many missing values or with too much or too little variation to be useful.

2. Ranking that sorts remaining inputs and assigns ranks based on importance.

3. Selecting that identifies the subset of features to use in subsequent models.

The PCA/Factor node provides powerful data-reduction techniques to reduce complexity of data. Two approaches are provided. The first one is Principal component analysis (PCA). In this statistical dimensionality reduction technique, the correlated features can be combined as principal components. The second one is Factor analysis. It identifies underlying concepts, or factors, that explain the pattern of correlations within a set of observed fields. Factor analysis focuses on shared variance only. Variance that is unique to specific features is not considered in estimating the model. Several methods of factor analysis are provided by the Factor/PCA node. For extended comparison we have received expert judgmental generic list of influencing factors, their attributes and weights for the studied segment from one of professionals of Ukraine credit market with more than 10 years of working experience.

For both approaches, the goal is to find a small number of derived features that effectively summarize the information in the original set of features and compare them with expert model.

To develop scoring models, IBM SPSS Modeler offers 16 base methods (some examples of these ones are: Decision Trees (CART, QUEST, C.5.0, CHAID), Neural Network, SVM, Bayes Network, KNN, Logistic Regression, Discriminant analysis) and large set of ensemble methods (bagging, boosting, Random Tree, Random Forest, XGBoost Tree XGBoost Linear, XGBoost-AS) [9].

Moreover, the Auto Classifier node creates and compares a number of different binary models, allowing to choose the best approach for development. 16 modeling algorithms are supported, making it possible to select the best methods, the specific options for each, and the criteria for comparing the results.

Concept used

Our investigation starts with the stages of pre-processing the dataset and adding new features that better describes defining borrower's status than initial ones. Than to the resulted dataset with initial number of features we applied modeling methods such as Decision Trees, Random Forest, Support Vector Machines, Neural Networks, Logistic Regression and Expert approach. After this stage we applied a number of feature selection techniques in order to decrease a number of features and conduct modeling again but under feature selection. We provide with analysis to compare results for AUC values between initial models and models under feature selection. Finally, we applied a

hybrid approach of feature selection analysis to obtain the optimal number of features, conduces in credit scoring accuracy increase. Described stages for investigational results are presented in Figure 1.

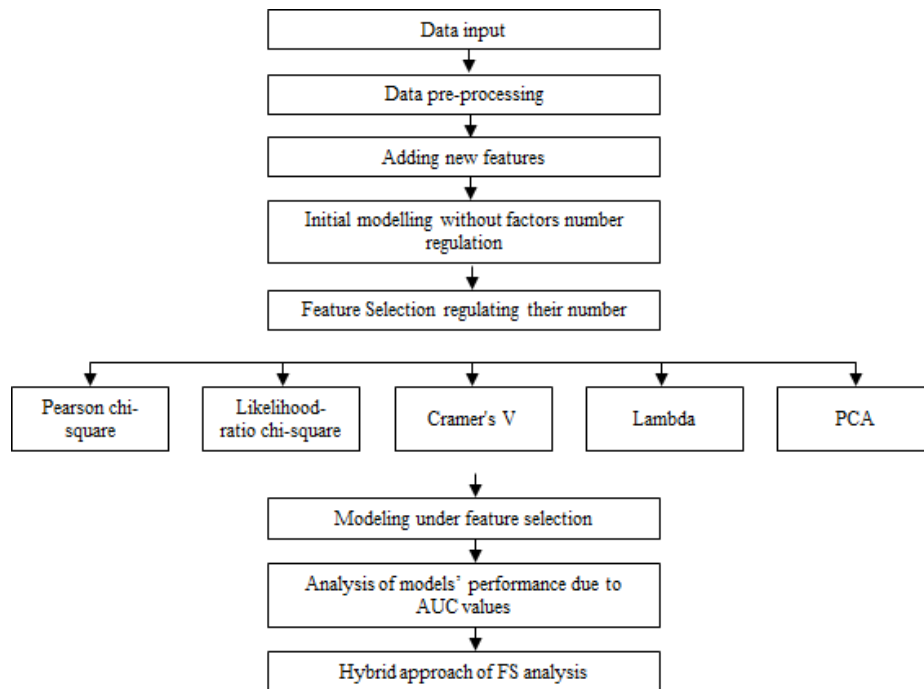


Fig. 1. Proposed concept for the experiment

Data pre-processing

Data pre-processing includes several steps:

1. Removing missing values and irrelevant features.
2. Data integration, transformation and normalization.
3. Reclassifying categorical values.
4. Balancing data.

Feature creation

The process of feature creation gives an opportunity to adjust business logic to the process of feature selection by adding new feature interaction rules. Adding new features gives more description for defining borrower's status than initial ones, should increase modeling results in order to improve banks' performance in credit scoring problem.

Feature selection

Feature selection is also a data pre-processing technique, which is used to select the relevant attributes for the experiment. Feature engineering is crucial for model optimization.

This paper proposes feature selection by ranking measures as Pearson chi-square, Likelihood-ratio chi-square, Cramer's V and Lambda and feature selection using Principal Component Analysis. All feature selection techniques in detail are presented below.

Feature selection by ranking measures.

Feature selection by ranking measures was used to screen and rank features by importance. In this paper, we focus on 4 ranking measures.

1. Pearson chi-square. Tests for independence of the target and the input without indicating the strength or direction of any existing relationship.
2. Likelihood-ratio chi-square. Similar to Pearson's chi-square but also tests for target-input independence.
3. Cramer's V. A measure of association based on Pearson's chi-square statistic. Values range from 0, which indicates no association, to 1, which indicates perfect association.
4. Lambda. A measure of association reflecting the proportional reduction in error when the variable is used to predict the target value. A value of 1 indicates that the input field perfectly predicts the target, while a value of 0 means the input provides no useful information about the target.

Feature selection by Principal Component Analysis.

Principal components analysis (PCA) finds linear combinations of the input fields that do the best job of capturing the variance in the entire set of features, where the components are orthogonal (perpendicular) to each other. PCA focuses on all variance, including both shared and unique variances.

Factor analysis and PCA can effectively reduce the complexity of data without sacrificing much of the information content. These techniques can help to build more robust models that execute faster than would be possible with the raw input fields.

Modeling

Typical methods for performing binary classification are Decision Trees, Random Forest, Support Vector Machines, Neural Networks, Logistic Regression [23]. Expert approach is an effective alternative for these methods.

In this paper, we focus on the four main methods as Support Vector Machines, Neural Networks, Logistic Regression and Decision Tree (CHAID). We are interested in achieving the best rate of AUC, because the higher is the value of AUC the better is the distinguishing capacity of the classifier. It means that the chosen features, set by the mentioned feature selection techniques provide the best combination of features given

that improves the capability of a credit models to correctly identify the behavior of a potential borrower to pay back a loan.

After comparing and sorting the results of AUC measures for the classification algorithm, the procedure of selecting best one takes place. Besides, in order to achieve better performance, the ensemble of chosen models can be developed.

A hybrid approach for feature selection analysis

To present an argument for reasonable feature selection, it is advisable to focus not only on the meaning of the measures described above. We suggest to implement a hybrid approach.

We propose to average the values of the statistical measures for each model for different number of fields, which will allow to obtain the number of features for selection that corresponds to the highest accuracy of the model. Taking into account active use of Principal Component Analysis, presented in the literature on this issue, it is also advisable to take advantage of the following approach: the weight for the PCA will be 0.5, and the remainder will be evenly distributed among the statistical measures (0.125 for each).

Based on the hybridization of the measures, we can arrive at conclusion that the AUC values depend (or not) on the number of features to be selected, and then we will obtain the optimal number of features and develop model using the best chosen quality approach.

To recognize the correspondence between the selection criteria and the models used, the AUC values for each measure for different number of features for each model have to be averaged. If a particular criterion takes precedence for most models, it can be used for feature selection and developing the ensemble of models

4 Experimental Results

Data pre-processing

Our experiment starts with the process of data pre-processing. First of all, data cleaning was performed (removing missing values and irrelevant features from the database). Fields were screened based on the following criteria: maximum percentage of missing values; maximum percentage of records in a single category and maximum number of categories as a percentage of records (for categorical fields), minimum coefficient of variation and minimum standard deviation (for numeric fields).

While proceeding data we found out that there is a conflicting coding scheme in the database. Numerical attributes had two ways of representing integer separators from fractional: a comma (field "WRK_EXPERIENCE") and a semicolon (all other numeric attributes), or another example: a date of birth field that has "-" or "." separators. There are also two data formats in the WRK_NROFEMPLOYEES field - categorical and date. Gender ("Female", "female") is also indicated by different formulations.

To prepare the data for modeling, we create a numeric field of the borrower's age, the flag field of the borrower's gender, where we reclassify the errors of entering the

gender data. Also we create new flag fields for the presence of a partner, attitude towards the army and reclassify the occupational names field to six occupations to facilitate further modeling.

Another important moment is creating new features in order to adjust business logic to the process of feature selection. Thus, we added new feature interaction rules: the amount of income per family member, the amount of income per child, the amount of loan per term and the amount of income per payments. The practicality of this step is noted in many sources [21, 23].

The role is set to target for the field that indicates whether or not a given customer defaulted on the loan. The potential target fields were EVER_1_DPD, EVER_30_DPD, EVER_60_DPD, EVER_90_DPD. We have chosen EVER_30_DPD as the target, because such loan delinquencies are beneficial for the bank, because the borrowers also pay delay penalty in addition to the loan repayments.

After data pre-processing a dataset of 34 fields was prepared instead of initial 62. It consists of 41687 records. The data is in several formats: numeric (24), categorical (8) and logical (2).

It should be mentioned that the resulted dataset was split into two samples: training (75%) and testing (25%). To correct imbalances in dataset we use Balance node that causes an artificial increase records for which the target field EVER_30_DPD returned "1". The process of balancing data is essential in order to decrease misbalanced in initial data where the percentage of non-repayable loan is low in comparison with repayable ones (that is typical in credit-scoring problem for real business cases). Since many modeling techniques have trouble with biased data, they will tend to learn only the positive cases (repayable loans) and ignore the negative ones. If the data are well balanced with approximately equal numbers of positive and negative cases, models will have a better chance of finding patterns that distinguish the two groups. In this case, a Balance node is useful for creating a balancing directive that increases cases for non-repayable loans. In order not to misrepresent the true distribution results we apply Balance node only to the training sample of the data.

Feature Selection Techniques and Modeling

This section provides us with AUC values for scope of methods with and without feature selection including expert approach model (Table 1).

Table 1. AUC results for scope of models.

Model	AUC value
Logistic Regression	0.601
Neural Networks	0.596
SVM	0.583
CHAID	0.696
Expert	0.654

Without using feature selection, Decision Tree (CHAID) model has demonstrated the best results while pure expert model showed second separation power. When scoring data uses Feature Selection node, the top n fields based on importance (4 different statistical measures) were selected (n = 30, 25, 20, 15, 10). Similar actions were performed for the PCA/Factor node. Next, Logistic Regression, Neural Network, Support Vector Machines, and Decision Tree (CHAID) models were built for each case. The choice of these models is explained by the results of the application of Auto Classifier node.

According to expert approach, 20 factors were determined as significant. The most valuable features are 'Loan payment to income ratio', 'Income to expenses ratio of borrower', 'Spouse availability' and 'Age of a borrower'. By significance all factors can be divided into 4 groups with same level of predictive strength with number of factors 3, 1, 10 and 6. By logical criteria all factors can be assigned to social-demographic, lending terms, financial state and lending history types. Further number of factors change is impractical as it is time consuming and contradicts to the aim of pure expert approach.

AUC results for models with feature selection for n equal to 25, 20 and 15 are presented in the Tables 2-5. Results for n equal to 10 and 30 are missed due to insignificant difference from 25 and 15 options respectively.

Table 2. AUC results due to feature selection technique for the Logistic Regression.

Number of features	(1) Pearson chi-square	(2) Likelihood-ratio chi-square	(3) Cramer's V	(4) Lambda	(5) PCA	(6) Average (1-4)	(7) Average (5-6)
15	0.740	0.749	0.746	0.745	0.681	0.745	0.713
20	0.748	0.749	0.747	0.749	0.594	0.748	0.671
25	0.746	0.748	0.747	0.747	0.589	0.747	0.668

Table 3. AUC results due to feature selection technique for the Neural Network.

Number of features	(1) Pearson chi-square	(2) Likelihood-ratio chi-square	(3) Cramer's V	(4) Lambda	(5) PCA	(6) Average (1-4)	(7) Average (5-6)
15	0.702	0.715	0.704	0.700	0.677	0.705	0.691
20	0.713	0.721	0.732	0.709	0.595	0.719	0.657
25	0.648	0.683	0.705	0.701	0.592	0.684	0.638

Table 4. AUC results due to feature selection technique for the SVM.

Number of features	(1) Pearson chi-square	(2) Likeli- hood-ratio chi-square	(3) Cramer's V	(4) Lambda	(5) PCA	(6) Aver- age (1-4)	(7) Aver- age (5-6)
15	0.657	0.673	0.67	0.678	0.507	0.670	0.588
20	0.679	0.671	0.672	0.679	0.582	0.675	0.629
25	0.638	0.673	0.686	0.685	0.580	0.671	0.625

Table 5. AUC results due to feature selection technique for the CHAID.

Number of features	(1) Pearson chi-square	(2) Likeli- hood-ratio chi-square	(3) Cramer's V	(4) Lambda	(5) PCA	(6) Aver- age (1-4)	(7) Aver- age (5-6)
15	0.702	0.675	0.688	0.716	0.686	0.695	0.691
20	0.695	0.684	0.718	0.69	0.697	0.697	0.697
25	0.729	0.668	0.714	0.721	0.680	0.708	0.694

It is obvious that PCA has proven to be an ineffective variable selection technique for CHAID and SVM, since the AUC values are close to the corresponding values in models without feature selection. The best results were achieved for logistic regression and model of neural networks according to criteria Likelihood-ratio chi-square and Cramer's V.

On average, the use of feature selection techniques improves the AUC value by 11.2% compared to the none-use. Note that the distribution of cumulative gain of AUC averages compared to the AUC averaged without feature selection is not uniform - the statistical criteria of Pearson chi-square, Likelihood-ratio chi-square, Cramer's V and Lambda improve by 13.0-14.7%, but Principal Component Analysis does only by 0.4%. That is why, it is advisable for the Ukrainian banks to try the alternative of feature selection by statistical measures, unlike the widespread foreign experience which prefers PCA [7, 11, 25].

The findings prove that in most cases with decreasing number of features, AUC measures for the classification algorithms increase, and cases reducing the variables to 20 improve models performance.

Hybrid approach of feature selection analysis

The tables 1-5 show the AUC results for a different number of input fields, selected in accordance with 5 feature selection criteria, as well as average values of 4 statistical measures and a weighted average of all presented measures (the maximum value is highlighted in grey).

AUC averages of all models (Table 6) confirm that the combination of statistical criteria allows to obtain the optimal number of features for modeling - 20, by PCA - 15.

Table 6. Average AUC results for the Logistic Regression, Neural Network, SVM, CHAID.

Number of features	(1) Pearson chi-square	(2) Likeli- hood-ratio chi-square	(3) Cramer's V	(4) Lambda	(5) PCA	(6) Aver- age (1-4)	(7) Aver- age (5-6)
15	0.700	0.703	0.702	0.710	0.638	0.704	0.671
20	0.709	0.706	0.717	0.707	0.617	0.710	0.663
25	0.690	0.693	0.713	0.714	0.610	0.702	0.656

It is obvious, that the value of AUC is higher using a uniform distribution of statistical measures, rather than using a weighted approach taking into account PCA.

An interesting fact is that with decreasing number of feature, we can observe their similarity tendency. The most frequently rated fields by feature selection technique are as follows:

1. CLN_YEARS (current age of a client);
2. WRK_FIELD (work field of a client);
3. SPOUSE (existence of a spouse);
4. INC_ALL_AP (total incomes of a client);
5. AMOUNT_PER_TERM (a sum of credit by term).

As it comes to the created features in order to adjust business logic to the process of feature selection, we should mention that all of them are selected for 20 important features by all criteria. Moreover, PCA takes them in the top six.

Attempts to determine the best feature selection technique by averaging AUC values in different models for different number of features were unsuccessful, as each model demonstrated different best measures): for the Logistic Regression - Likelihood-ratio chi-square, for Neural Network - Cramer's V, for SVM - Lambda, for CHAID - Pearson chi-square. As none of the criteria was overweight in most models, we concluded that the ensemble was inappropriate in this case.

5 Conclusion

The study shows processes of data pre-processing, feature creation and feature selection that can be applicable in real-life business situations for binary classification problems by using nodes from IBM SPSS Modeler. Results have proved that application of hybrid model of feature selection, which allows to obtain the optimal number of features, conduces in credit scoring accuracy increase.

Proposed hybrid model comparing to expert judgmental approach performs in harder explanation but shows better accuracy and flexibility of factors selection which is advantage in fast changing market.

Besides, the paper shows the accessibility of the approach for users of analytical platforms, the availability of tools in business application packages (IBM SPSS Modeler as an example) and the method of combining these tools. It is obvious that using

feature selection techniques differ among countries, so the results of this particular study can be implemented in real business cases in Ukraine.

It should be noted that Ukrainian banks may be advised to try using the feature selection according to such statistical measures as Pearson chi-square, Likelihood-ratio chi-square, Cramer's V and Lambda, rather than PCA. The study results of Ukrainian lending market also show that the choice of features can be limit to 20, which allows to obtain the maximum AUC value.

The study empirically confirms that in Ukraine banks should consider hybrid selection technique with equal weights for statistical measures. The results show that the usage of a hybrid approach to feature selection methods improves the AUC value compared to the none-use by 11.2%, which is a clear advantage. On the other hand, the weak point of the approach is the increase of amount of time spent on calculations.

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Open Data in Electrical Energy Balancing of Ukraine: Green Deal and Security Aspects

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Abstract. The implementation of The European Green Deal is a modern driver of changes in the energy sector for transition to a clean economy and energy security. Access and sustained consumption of clean energy sources, reduction of greenhouse gas emissions and environmental pollution are important initiatives for overall socio-economic development. This all implies the need to develop models for the analysis the state of the energy system in real time as well as predict general energy consumption based on available open data and balance databases. In this manuscript, we investigate the importance of open data for energy security and the development of effective energy policy and institutional frameworks. Analysis of the electrical energy balance of Ukraine (the 2019 calendar year) on the base of the open data shows the existence of volatility between the production of electricity from renewable energy sources and its consumption, which may directly affect the country's security.

Keywords: open data in energy sector, electrical energy balancing, energy security in Ukraine.

1 Introduction

In order to analyze the state of the energy system in real time, to predict internal process, and, especially, to develop energy policies at all levels of governance, the availability of open energy data is important. Currently, energy systems in most countries are being modernized and developed based on the concept of deep integration of electric power grids and computer information and communication networks. Developing access to modern energy database for users is not a main challenge, but also strongly multidisciplinary linked to other aspects such as geography, health, education and equality. Using Open data gives fresh perspectives for scientific community and policy-makers to create efficient energy systems. Furthermore, extension of Open data, grids databases such as electricity generation capacities, consumption, electrical loads, geo-referenced data promote to fill knowledge gaps and contributes to energy SDG targets and Green Deal agenda [1]. Ukraine also have obligations in several environmental, energy and climate partnerships [2].

Special attention in the research made on interconnection among availability of Open electrical energy data and credibility of research for energy systems development based on energy balancing methodology. The electrical energy balance lets to study the domestic electrical energy situation, to monitor effects of national electrical energy policy of a country [3] and to compare balancing activities at the international energy market.

2 Recent Research Analysis

2.1 Related Works on Energy Balancing

The problem of energy balance has been studied extensively for the past decade. Actually, there are many theoretical and practical approaches developed in the field of electric energy balance. Fig. 1 shows the number of publications with TITLE-ABS-KEY “Open Data&Energy” per year in accordance with Scopus database of peer-reviewed literature. The exponentially growing number of publications per year proves that the open data in the context of electric energy balance is currently a trendy topic of research.

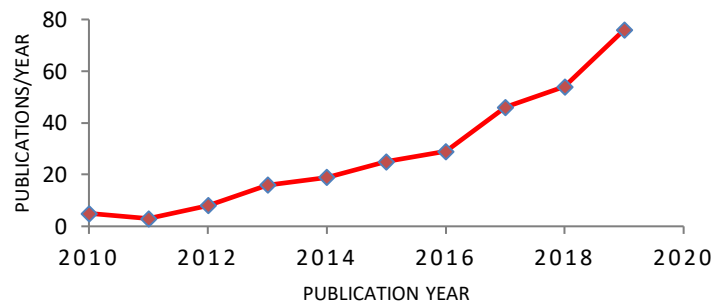


Fig. 1. Number of publications per year under the topic “Open Data&Energy” listed in the source index of the Scopus (Source: Conducted by authors based on Scopus database [4])

However, the peculiarities of application open data in electrical energy balancing faces a lack of methodological approaches. This is mainly because of significant complexity of the problem. Researchers as well as policy makers in energy sector generally emphasizes the importance and urgency of the issue, but also its multiplicity and difficulty. Pfenninger et al. [1] prove the need of open and high-quality big data to develop quantitative energy models, which is the basis of well-thought-out energy policy at all levels of government. In Wiese et al. [6] the lack of transparency of energy models as well as lack of an open source energy system for developing a sustainability strategy are discussed. The author emphasizes the importance of expertise from different fields on technical, economic, environmental, and social issues for modeling a complex system as renewable energy pathways simulation system.

It should be noted about some ethical and security concerns around open data. Collecting data, formulating models might encounter problem with access to sensitive commercial data or to data containing individual households' information. Costs of security failures in smart grid deployments have analyzed by McDaniel and McLaughlin [7]. Simmhan et al. [8] note that security and privacy concerns inherent in an information-rich Smart Grid environment. Such situation can be exacerbated by their deployment smart grid software architectures on clouds.

Energy security and current transformations in the economy are highlighted in the literature. Effects of energy convergence are analyzed for example in Rui et al. [9]. Authors in [10, 11] shows importance of balanced resource allocation at all levels of governance. Vasylieva and Prymenko in [12] focused on the concept of "energy dependence" through energy security of all types of energy resources by using Jewell model. In addition, authors in [13] develop methodical approach that allows to assess the overall level of energy security of the country with further minimization of integral specific discounted environmental and economic costs. By using IEA Model of short-term energy security, the energy security of Ukraine is assessed. Karakasis in [14] focus on policy paradigms for energy security matters. By conducting open-ended interviews with the opinion-makers, author come to conclusion that there is difference between the academic and the policy world in energy fields.

Many authors in their papers [15] confirm that biogas is the most perspective alternative resources and expected to bring benefits for the environment and economy [16]. Effects that take place through reduction of the natural gas consumption and replacement by alternative fuel types are analyzed for example in [17], which finds additional budget stimulation for local energy market transformation. From a different perspective, a methodological approach to electricity pricing on local level is developed by Mentel et al. [18] in the form of accounting a balance of electricity production and its consumption by the population of a particular territory. It is important to highlight the implementation of the Net-zero building concept to gain energy security. In [19] researchers make the economic assessment of the different power of solar collectors and energy consumption by the households taking into account principles of Net-zero building.

Several empirical studies indicate that green investments have a positive effect on economy and energy security. Lyeonov et al. in [19] estimates that green investment could provoke the growth of GDP per capita by 6.4% and the increase of renewable energy by 5.6% in the total final energy consumption. Similar arguments are presented by Marcel in [21]. Author by using Stationery and Johansen cointegration tests, VAR model, and Granger causality determines relationship between electricity consumption and economic growth. In manuscript, bidirectional causality is empirically proven. Some authors [22, 23] emphasize on impotence of green bonds as incentive instrument for realizing green and renewable projects.

2.2 Open Data for Quality of Science in Energy Fields and Energy Policy

According to European data portal [24], "Open data" is data that anyone can access, use and share. In other words, it's a tool for the digital age that brings social, economic

and environmental benefits. The Open Knowledge Foundation [25] specify Open data on two characteristics to openness: legal openness (legal to build on and to share it - open license, placing into the public domain, etc.) and technical openness (no technical barriers to using data - machine readable, available in bulk, etc.). Moreover, Foundation defines principles of Open data: availability and access; re-use and redistribution; universal participation.

Importance of open data for energy security are determined by the following factors:

- the constantly growing demands both on environmental friendliness and on improving the efficiency of energy systems and networks;
- the unstable nature of wind and solar power generators that increases the requirements for efficient and fast load management in power systems;
- the need for effective management of distributed generation systems with a large number of sources;
- the need for accurate load energy forecasting and efficient management of network elements to save energy and prevent congestion.

Increasing the relevance of the topic of the energy balance and the availability of open data requires creation of a specific online collaboration platform across science and policy. The interconnected factors that influence quality of science in energy fields and energy policy are presented in Fig. 2.



Fig. 2. The importance of open data for quality of science in energy fields and energy policy (Source: Conducted by authors)

The role played by Open Data and Big data as a tool for research in different fields of science has been intensely debated in the academic literature over the last years [26, 27, 28, 29]. In Beyi [30], the link between the individual and the digital network is explained through new market mediator tools for creating global social dialogue.

Summarized literature review on place of Open and Big data in the contemporary world is discussed in [31].

3 Data and Methodology

3.1 Data

Our research based on the course of the hour-by-hour electrical energy balance of the Integrated power system (IPS) of Ukraine. The data were upload from the Open data portal of Ukraine (that fully integrated into the European data portal). The electrical energy balance databases on the portal available from the 2016 year, but we used electrical energy statistics refer to the 2019 calendar year only (from January to December on the hour-by-hour basis). The daily cycle of electrical energy balance stats at 01:00 a.m. and ends at 12:00 p.m. The data in electrical energy balances were presented in megawatt-hours (MW). The accuracy of the electrical energy balance data in some cases not very good. Firstly, in the 2019-year database, we found missing data for two observation hours (see Fig. 3). For the purpose of research, we had to make corrections of empty cells with the values above (empty cells at 4:00 p.m., 17.12.2019) and below (at 5:00 p.m., 17.12.2019). Secondly, we observed some errors in volumes of computed index ‘Used for the internal market’ electrical energy. The “statistical difference” in energy balance not high but indicates “that some reported elements are inaccurate (or alternatively, some elements are not reported)” [3]. Thirdly, this database has two different names on the portal (‘Hour-by-hour balance of the IPS capacity of Ukraine’ and ‘Electrical energy production and consumption balance (forecast and actual)’).

3.2 General Model

The electrical energy statistics collected by the National power company ‘Ukrenergo’ [32] according to the statistical methodology of Ukraine. The presented approach not fully harmonized with Eurostat’s energy statistics approaches. We tried to apply definitions of Regulation (EC) No 1099/2008 on energy statistics [33], but not all data were covered. ‘Ukrenergo’ does not report these data points: geothermal, wind power production (but publish the value of renewables); total fuel consumption in main activity producer plants. Electrical energy balance of Ukraine possible to describe by following equations (1-6):

$$E_{TEP\ i} = E_{NPP\ i} + E_{THPP\ i} + E_{TPP\ i} + E_{other\ renewables\ i} + \varepsilon_{ld\ i} \quad (1)$$

$$E_{THPP\ i} = E_{HPP\ i} + E_{CHPP\ i} + E_{PSP\ i} + \varepsilon_{ld\ i} \quad (2)$$

$$E_{TNEP\ i} = E_{TEP\ i} - E_{Consumption\ i} + \varepsilon_{ld\ i} \quad (3)$$

$$E_{UIM\ i} = E_{TNEP\ i} + E_{TNEI\ i} - E_{usedPSP\ i} + \varepsilon_{ld\ i} = 0 \quad (4)$$

$$E_{TNEI\ i} = E_{TEI\ i} - E_{TEE\ i} + \varepsilon_{ld\ i} \quad (5)$$

$$E_{TNEI\ i} = E_{NEI\ EU\ i} + E_{NEI\ R-B\ i} + E_{NEI\ M\ i} + \varepsilon_{ld\ i} \quad (6)$$

where E_{TEP_i} – total electricity production (MW) in the i -balance ($i = 1, \dots, N$), E_{NPP_i} – nuclear power production (MW), E_{THPP_i} – total hydro power production (MW), E_{TTP_i} – conventional thermal power production (MW), $E_{other\ renewables\ i}$ – other renewables (not including hydro power production, MW), ε_{ld_i} – losses (transformation, distribution and transmission losses) and statistical difference (MW) in the i -balance, E_{HPP_i} – hydro power production (MW), E_{CHPP_i} – combined heat and power plant production (MW), E_{PSP_i} – part of hydro produced from pumped storage (MW), E_{TNEP_i} – total net electricity production (MW), $E_{Consumption_i}$ – electricity consumption (MW), E_{UIM_i} – used for the internal market (MW), E_{TNEI_i} – total net electricity imports (MW), $E_{usedPSP_i}$ – electricity used for pumped storage (MW), E_{TEI_i} – total electricity imports (MW), E_{TEE_i} – total electricity exports (MW), $E_{NEI\ EU_i}$ – net electricity imports to EU (MW), $E_{NEI\ B-R_i}$ – net electricity imports to Belarus and Russia (MW), $E_{NEI\ M_i}$ – net electricity imports to Moldova (MW).

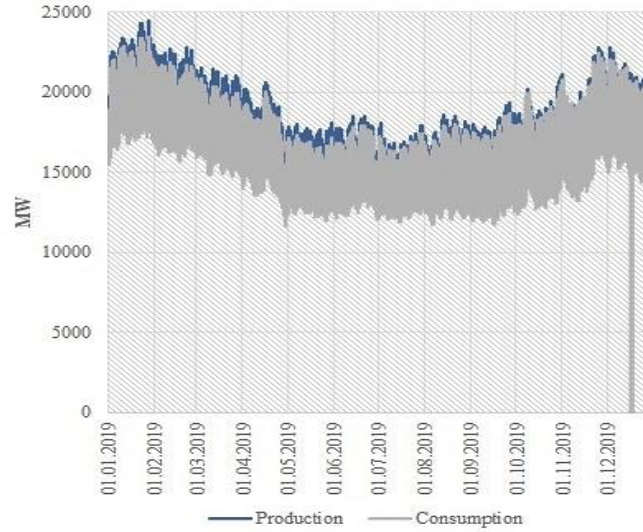


Fig. 3. Hour-by-hour electrical energy balance of the IPS of Ukraine in 2019 (Source: Conducted by authors based on the data of the Open data portal (ODP) of Ukraine [32])

The general regression model of electrical energy balance based on equations (1-6) is as follow (7):

$$Y_i = f(X_i) + \varepsilon_{ld_i} \quad (7)$$

where Y_i – dependent variable, X_i – independent variables in the i -balance ($i = 1, \dots, N$).

To test differences between electricity consumption and renewables power production, we set the hypothesis is as follows:

H_0 : No difference between means of electricity consumption and renewables power production.

Ha: Difference between means (means of electricity consumption and renewables power production is not equal to another).

The data set of electrical energy balance has a high range of values. To apply statistical testing, we used a normalization procedure in Python to change the values to a common scale. The general statistics were computed in Python with Pandas, SciPy, the Scikit-learn, Statsmodels modules.

4 Results

Ukrainian electricity production generally orients on the internal market. The peak and the most significant variation values of electrical energy production and consumption were observed in January 2019. But the highest mean values of production and consumption were in February 2019. The lowest level of electrical energy production and consumption occurred during the warmest seasonal period in Ukraine: from May to October. But if we look at renewable power production, are visible differences between electrical energy consumption and renewable power production (see Fig. 4). This situation arises in connection with the production of electricity from new renewable energy sources (other renewables in Ukrainian case). Operators and agents in the energy market balance the production and consumption of electricity not only through pumped storage but within combined heat and power plant production (E_{CHPP} , Table 1). Export-import operations are not the main source of the electricity market balancing in Ukraine due to existing restrictions in this area. The Ukrainian electricity market is only by 6 % synchronized with the EU market. The rest of the energy is flowing between Ukraine and Belarus, as well as between Ukraine and Russia, although Russia is proclaimed a military adversary of Ukraine. And therefore, the uncontrolled and unsystematic production of electricity from new renewable energy sources strengthens Ukraine's dependence on Russia through the problem of balancing the production and consumption of electricity. And may worsen the energy security of Ukraine.

The OLS regression on electrical energy balance analysis results on following as:

- the total hydro power production is explained by 54,2 % of the variation in electrical energy consumption (Table 2); the 94,7 % of the variation in electrical energy consumption is explained by total electricity production (Table 3);
- there is a significant difference in means (Table 2 and Table 3), so we should reject the H_0 hypothesis, and accept the H_a hypothesis;
- The F-statistic = 1.036 for the total electricity production and F-statistic = 1.559 for the total hydro power production, which is indicating that there is a significant effect of electrical energy production on consumption; this indicates that the overall regressions are meaningful.

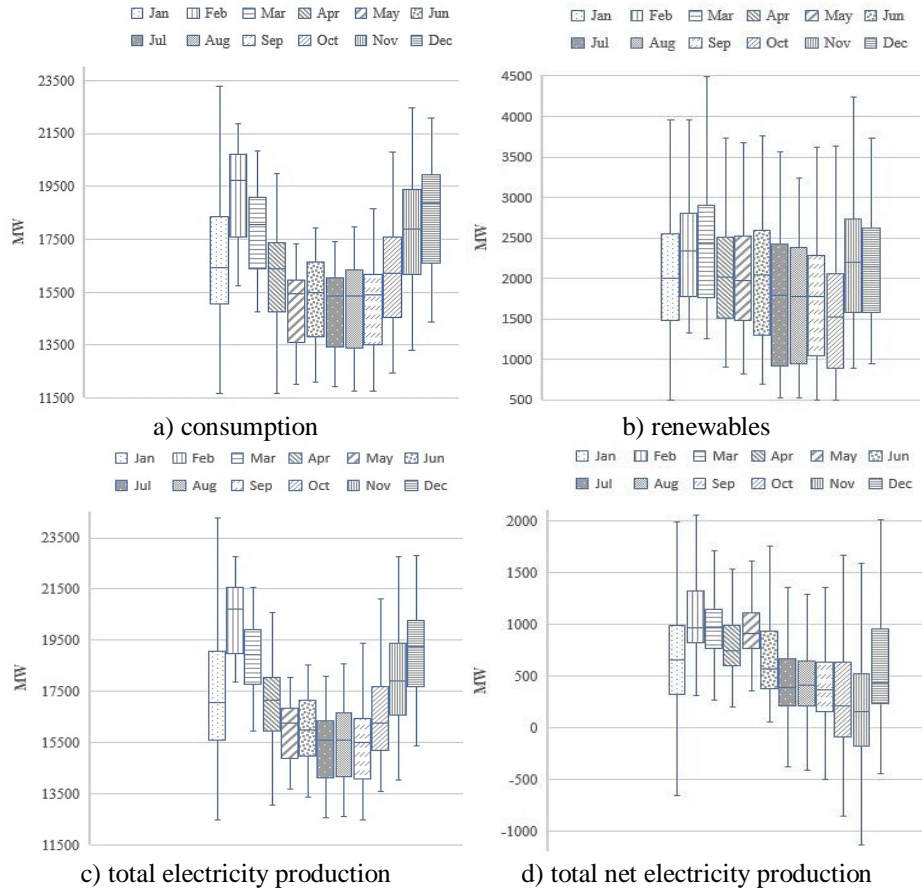


Fig. 4. Box and Whisker charts of electrical energy balance of Ukraine in 2019 (Source: Conducted by authors based on the data of the ODP of Ukraine [32])

Table 1. Correlation matrix between electricity consumption ($E_{Consumption}$) and other electrical energy aggregates (Source: Conducted by authors based on the data of the ODP of Ukraine [32])

E_{NPP}	E_{HPP}	E_{CHPP}	E_{PSP}	E_{THPP}	E_{THPP}	$E_{other\ renewables}$	E_{TEP}	E_{TNEP}	E_{NEIR-B}	E_{NEIM}	E_{NEIEU}	E_{TNEI}	$E_{usedPSP}$	E_{UIM}
0.658	0.496	0.748	0.422	0.736	0.699	0.035	0.973	-0.239	-0.044	-0.498	-0.034	-0.107	0.448	-0.005

Table 2. OLS Regression results: $E_{Consumption}$ and E_{THPP} in 2019 (Source: Conducted by authors based on the data of the ODP of Ukraine [32])

Dep. Variable:	$E_{Consumption}$	R-squared:	0.542
Model:	OLS	Adj. R-squared:	0.542

Method:	Least Squares			F-statistic:	1.036e+04	
No. Observations:	8759			Prob (F-statistic):	0.00	
Df Residuals:	8757			Log-Likelihood:	-77454.	
Df Model:	1			AIC:	1.549e+05	
Covariance Type:	nonrobust			BIC:	1.549e+05	
	coef	std err	t	P> t	[0.025	0.975]
Intercept	1.283e+04	41.960	305.836	0.000	1.28e+04	1.29e+04
E_THPP	2.3577	0.023	101.788	0.000	2.312	2.403

Table 3. OLS Regression results: E_Consumption and E_TEP in 2019 (Source: Conducted by authors based on the data of the ODP of Ukraine [32])

Dep. Variable:	E_Consumption			R-squared:	0.947	
Model:	OLS			Adj. R-squared:	0.947	
Method:	Least Squares			F-statistic:	1.559e+05	
No. Observations:	8759			Prob (F-statistic):	0.00	
Df Residuals:	8757			Log-Likelihood:	-68023.	
Df Model:	1			AIC:	1.360e+05	
Covariance Type:	nonrobust			BIC:	1.361e+05	
	coef	std err	t	P> t	[0.025	0.975]
Intercept	-740.9104	44.577	-16.621	0.000	-828.291	-653.530
E_TEP	1.0022	0.003	394.872	0.000	0.997	1.007

5 Conclusions

Our study showed a significant interest increase in the energy sector, especially in renewable energy matters. Open data should help researchers conduct analysis. But the presented databases in the energy sector are not always available, relevant, and meet the requirements for the quality of research. All these shortcomings correspond to Ukrainian open data in the energy sector. The data in the energy sector is published only by 18 percent on the Ukrainian open data portal; the same databases have several names; some data are absent in the databases, and there are errors in the calculations.

However, open data is quite necessary for balancing electrical energy. An analysis of the production and consumption of electricity allows us to see the problems of balancing, which can affect the energy security of the country as a whole and individual contractors in particular.

The data test displays that stimulating the electricity production from renewable sources in Ukraine not only leads to green energy consumption but also significantly increases the volatility between production and electricity consumption, the dependence on neighboring countries to balance the electrical market. And since one of the

neighboring countries is Russia, the current situation causes the need for electrical energy balancing therapy in a short period and conceptual changes the source of renewable power production in a long period in Ukraine.

Acknowledgment

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Modeling of Effectiveness of Media Investment Based on Data Science Technologies for Ukrainian Bank

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Abstract. The objective of this paper is to research, modeling and forecast the call-center workload that depends from all media and marketing activities. Data mining approach and machine learning technologies help to clearly identify and distinguish the impact factors on the feedback of potential customers (both positive and negative), determine which communication channels to use to increase inflow of queries. The model for forecasting of effectiveness of media investments and as a result managing of Return of Marketing Investments (ROMI) based on hourly data for all calls to Call Center, media and marketing indicators and macroeconomic factors for banking sector in Ukraine for the period 2013-2018 years was built. Authors used such machine learning technology as econometric modeling (regression analysis) for key metric “Incoming Calls to the Call Center”. Data Science technologies help to forecast and manage calls flow with average error that is less than 10%. Article describes how to increase the effectiveness of advertising campaign by 8% in the first 2 months and achieve potential growth of conversion rate by 58%, compared to the standard market level. This article contains the key stages of implementing data mining approach, directly in the process of machine learning and dwell on the important technical aspects of the implementation of forecasting models.

Keywords: data science, marketing, media, machine learning, ROMI.

1 Introduction: market context and business tasks

Businesses today need progressive solutions, and Data Science is a huge, bottomless area to look for. Data analysis is used for both operational and tactical tasks and strategic decisions. The media sphere is no exception. Own data approaches that integrate Data Science, comprehensive expertise and MarTech will be the most valuable resource for optimizing marketing investments and differentiating companies on the market. Predictive analytics is the defining technology of the 21st century and will increasingly be used to solve complex problems, challenges and bring tremendous value to businesses and all humanity.

The researches of the use of machine learning technologies and Data Science for modeling the marketing activity of enterprises were undertaken by such domestic and

foreign scientists as Bazhenov Y., Batra R., Burnet J., Büschken J. [2], Guz M., Lukanets T., Lysenko Y., Panasenko A. A. [10], Pankratov F., Pargelova A. [9], Romat E., Rositer J. R., Sandage C., Freiburger V., Shakhov D. A. [10], Shapiro S. and others.

A significant amount of research has been conducted on this topic. Marketing (media) mix modeling is the most commonly used method that involves building a regression model on historical data to display business metrics (sales) as a function of marketing and advertising variables, such as media activity, number of impressions, price index, and another variables such as seasonality, weather, market competition.

Mathematical modeling and data analysis open up many opportunities in the implementation of marketing activities of any enterprise. Thus, Chan and Perry (2017) [3] emphasize the importance for businesses to use different approaches to marketing modeling, because advertisers need to understand the effectiveness of their media and marketing spend in driving sales in order to optimize the allocations of marketing budgets. According to their research, the potential of MMM is often limited by the lack of detailed and qualitative data. As a solution they propose to develop better data and models, as well as to test models using simulations as the main areas of improvement for MMM.

Kiygi-Calli et al. (2017) [8] research the case in which data for creating models of advertising response are available every hour, while management decisions can relate to different time intervals (hour, day, week, month). The main conclusion is that models for low-frequency data are much simpler, while models for high-detailed data require to estimate a seasonal component. Using ad-stock approach, Zantedeschi et al. (2016) [16] determine the levels of decay of advertising message for all media, which allows in the process of developing a marketing strategy to forecast and take into account the actual short- and long-term advertising effects of each communication channel.

The contribution of regression analysis to media decision-making is quite significant, but there are alternative methods. Dawes et al. (2018) [5] describe evidence-based methods that have been shown to be useful for forecasting problems. Jin et al. (2017) [7], Zhang and Vaver (2017) [17] suggest using Bayesian hierarchical modelling.

The objective of this paper is to research, modeling and forecast the call-center workload that depends from all media and marketing activities using data mining approach and machine learning technologies for increase inflow of queries to the bank.

7 years ago, a political crisis took place in Ukraine, which caused significant economic crisis, when the Ukrainian national currency has fallen almost 4 times, from 8 to 30 UAH per USD. The financial sector was one of the first to face the economic downturn. Ukrainians have lost trust in banks, as evidenced by the significant decline in the consumer confidence index [12]. For 2014-2015 years credits, deposits in UAH and in foreign currency fell by 38%, 8% and 57% respectively [13].

Media activity of the financial sector is reduced to a lowest level, a lot of companies forced to stop mass media communications in media. Only a few biggest banks trying to maintain the confidence of Ukrainians with image campaigns on air [14, 15].

One of the Ukrainian banks, which is included in TOP 10 banks, had small and short media activity for the last 4 years. 2 years ago, media agency needed to develop a media strategy for the bank. In recent years there has been only one attempt at a media campaign in 2016. But the campaign was soon completed due to low response rate and 2 years the company didn't use media for communication with their audience.

There was a business task in the implementation of the campaign, which will give a maximum response to the calls to the Call Center. The main challenge is to develop the optimal full media mix, which include TV and other channels, and the best budget allocation for the media instruments. The key criterion is to achieve a positive Return of investment (ROI), otherwise current investments can be recognized as ineffective.

2 Data Mining approach as a good instrument to find effective business solution

Project was deploying in accordance with the most widely-used analytics model CRISP-DM [1, 11]. CRISP-DM describes the process through 6 main stages phases: "Business Understanding, Data Understanding, Data Preparation, Modeling, Evaluation and Deployment". The process involves the possibility of a flexible transition between phases in any order, going back when the need arises. Data Mining has cyclic nature, as the process of finding solutions continues after the project has been deployed. The key learnings and experience from previous cycle can generate new, more deeper business questions, which have positive influence on future data mining processes [4].

At the beginning of the project there was not enough information to make the best decision, because we had only partial information about the actual results, so the following databases were collected:

1. Detailed all available business indicators from the client for previous advertising campaigns throughout 2013 – 2016 years [6, 14, 15].
2. Open data about socio-economic development of Ukraine and consumer sentiment of population, use of banking products in dynamics [12, 13].

This was one of the key stages that allowed us to assess more accurately the market situation and take this into account when planning media activity.

The key idea was that we should combine the classic approaches of media planning (concentrate on share of voice, frequency of contacts with consumers and coverage of target audience) with completely new approach, which focus only on business indicators (calls, sales, conversion rate). Such approach to work with business client's based on data science, machine learning technologies and deep use of data.

3 How Data Science helps to increase efficiency of media investments

We have changed the traditional approach to media activity planning by focusing on modeling and forecasting key business indicators directly in order to effectively monitor business performance on a daily and weekly basis.

A regression model with a dependent variable called "Incoming calls to the Call Center" was built using Excel and R-Studio software. During the project implementation on the basis of databases of the bank, agency and open sources on business and socio-economic indicators, mathematical methods of data analysis and forecasting were used. Factors that influenced the conversion from media activity to calls, and from them

to orders and sales, were also evaluated, and these factors were improved to obtain the highest conversion rate. Two econometric sub-models were built to control and plan business at different stages of marketing activity:

1) Model for weekly planning. Control the performance of business KPIs and forecasting business results on a weekly basis allows you to quickly react to all changes and make tactical actions. The model allows you to estimate the impact of advertising and other positive or negative factors at any time that determine the level of business result.

2) Model for daily planning. Updating the model on a daily basis allows you to plan the hourly workload of the bank's Call Center accordingly to the amount of advertising activity. The correlation between the volume of realized TV ratings during the day and incoming calls to the Call Center was estimated. We evaluated the effectiveness of TV activities for every day of the week and each hour respectively.

This model optimized the work of the Call Center, as the forecast of calls for the next week was updated on a weekly basis, considering the actual results of TV activity and calls to the Call Center in the previous week.

The optimal model is multiple regression model with more than 30 factors due to daily and hourly specifications and looks like this:

$$\begin{aligned} \text{Calls_by_hours} = & \text{hours_coefficient} * \text{day_coefficients} * (\text{Constant} + a1 * \text{Adstock}(\text{TV1}) * \\ & + a2 * \text{Adstock}(\text{TV2}) + \dots + an * \text{Adstock}(\text{TVn}) + b * \text{Radio} + \\ & + ci * \text{billboards}_i + di * \text{Integrated_economic_indicator}_i) \end{aligned} \quad (1)$$

where *Adstock* is the instant, prolonged and lagged effect of advertising on consumer purchase behavior, which indicate influence of TV activity during a time. $\text{Adstock}(\text{TV})_t = \text{TV}_{t+a} * \text{Adstock}(\text{TV})_{t-1}$. *Integrated_economic_indicator* include dynamic of GDP, income level and dynamics of the use of banking products.

The model is quite complicated from a technical point of view, because is a combination of patterns for every day and every hour. To determine the technical characteristics of the model below is an example of one of the models (table 1).

Table 1. Technical characteristics of one of the models

Indicator	Coefficient	Stand. Error	t-statistics	P-value
Constant	19,78	5,97	3,31	0,0017
Economic indicator	-3,82	0,08	-50,44	0,0000
Billboard	32,98	0,42	77,77	0,0000
Radio	65,24	4,45	14,67	0,0000
TV1	158,53	0,75	211,77	0,0000
TV2	140,34	1,08	130,09	0,0000
TV3	178,96	1,45	123,61	0,0000
TV4	110,27	7,70	14,32	0,0000
Multiple R ²	0,97		Adjusted R ²	0,97
F-statistics	11894,423		p-value	0,0000

The main criteria of technical model optimization were increasing of R^2 , avoidance of problems of autocorrelation, heteroskedasticity and multicollinearity. Results: model estimates of factor's influence with probability at 95% level, $R^2 = 97\%$, homoskedasticity, avoidance of autocorrelation. The main criteria of business optimization were sales increase. Model coefficients have been changed due to data confidentiality.

The creation of a regression model made it possible to evaluate the impact of factors and develop recommendations for maximizing the effectiveness of media activity:

1) The optimal duration of campaign to minimize the wear-out effect.

Exceeding the pressure of the flight at X target rating points (TRPs - the main indicator of television activity) (Y weeks), leads to a decrease in the efficiency of TV activity as a result of the wear-out effect (fig. 1). Recommendation is that you continue to maintain the flight's duration at the necessary level of TRPs to maximize efficiency.

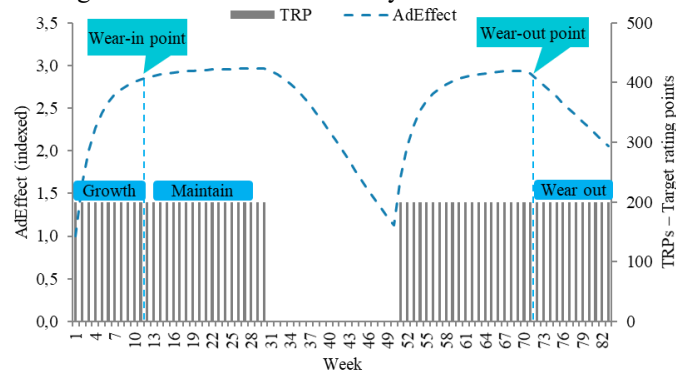


Fig. 1. Wear-out effect (data from bank's internal data base [6], media data bases [14, 15] and authors' calculations)

2) We recommend to rotate the video rollers in the period of campaign for additional calls growth and reduction of the wear-out effect.

Changing the creative allows you to increase incoming calls by 19%, but it doesn't compensate for the wear-out effect. In case of short TV campaigns, our recommendation is to use different creatives for all flights. So, we'll reduce the wear-out effect.

3) We recommend placing only X" roller (fig. 2).

Taking into account the price, placement of X" by the roller has higher efficiency: our recommendation is to use a long video to achieve the business KPIs.

4) We use additional activity on another communication channel at the end of the TV flight to accumulate incremental coverage and increase incoming calls (fig. 3). Another communications channel generates additional calls to calls from TV activity: start of advertising activity provides the incremental calls in every day on air (+ 20% in addition to calls from television).

Also, tactical recommendations on TV placement were developed based on the regression modeling and day by day tracking of business parameters:

1) Placing on weekends and holidays has low efficiency and we don't recommend to use activity in this period. The scenario with media activity at the weekend generates lower number of incoming calls, which reduces the effectiveness of each TRPs.

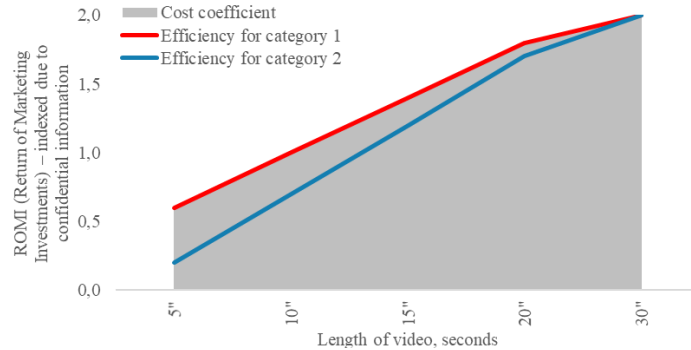


Fig. 2. Efficiency of different duration of creative materials (data from bank's internal data base [6], media data bases [14, 15] and authors' calculations)

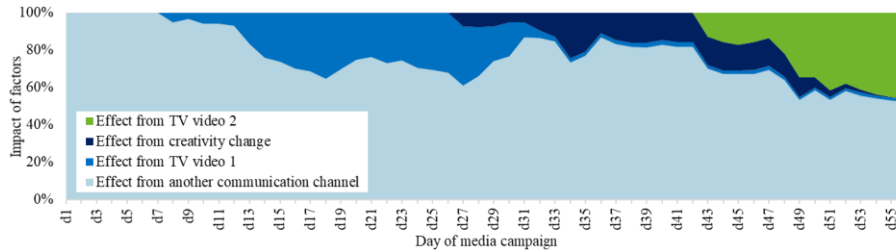


Fig. 3. Model decomposition (data from bank's internal data base [6], media data bases [14, 15] and authors' calculations)

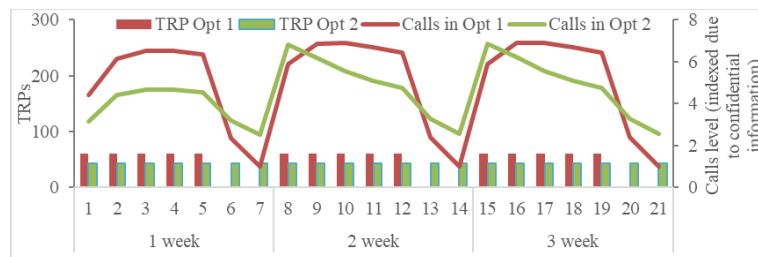


Fig. 4. Calls to the Call Center in different scenario of TV activities' allocation during a week (data from bank's internal [6], media [14, 15] and open data [12, 13] and authors' calculations)

2) Our recommendation is to use uniform distribution of advertising activities during the day, limiting placement in the evening. The mathematical model allowed us to estimate that (Fig. 5): the effect from placement in the evening is lower than during the day and in the morning. The influence of the evening placement to the next day is the same as the daily activity. We do not recommend to increase activity in the evening to stimulate calls the next morning or day.

Such recommendations cannot be taken simultaneously for all companies in the market, as the results are a combination of many factors and conditions that are formed at each time, which requires an individual approach in each case.

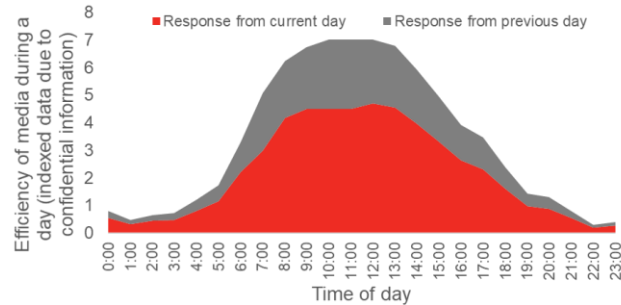


Fig. 5. Number of calls with a uniform distribution of TV ratings throughout a day (effectiveness of TV activity in every hour) (data from bank's internal [6], media [14, 15] and open data [12, 13] and authors' calculations)

4 Conclusions

Therefore, using of machine learning and data science techniques made it possible to make conclusions and develop recommendations for optimization media strategy aimed at the bank's business KPIs maximization: strategic and tactical recommendations for the most effective media mix (incl. TV); necessary volume of media pressure in all communication channels; optimal TV pressure per hour, day and week to maximize the amount of incoming calls to the Call Center.

We changed the approach of media planning for the Ukrainian advertising market, focusing at the first priority on the methodology of data science and machine learning for business data and shifting the traditional parameters of the media campaign's effectiveness on the second priority. Business indicator has become a key.

Working in the conditions of limited information in the market, we step by step collected a unique database, processed it with the help of machine learning methodology and as a result achieved high results. Due to a significant change in the model of planning, we optimized the advertising cost by 14% and achieved a higher conversion rate by 58%, compared to the average level in the market. Also, planning the traffic workload in the Call Center on the basis of the model allowed to properly distribute the workload of the Call Center and minimize possible loss of clients due to high calls flow.

By monitoring the actual results and building econometric models using machine learning tools, the optimal combination of factors was obtained on a daily and weekly basis. The models created an opportunity to evaluate and forecast the results of advertising activity (its effectiveness) on a regular basis. The average forecast error didn't exceed 11% and 8% for daily and weekly forecasting respectively, which confirms the high quality of the model and the received recommendations.

It is recommended to consider the following conclusions for future media campaigns:

- Optimal media pressure by target rating points (TRP) and period by weeks on air;
- The necessary period of a break without activity for restoration of response;
- Placement only X" roller;

- Lack of placement in days and time intervals with low efficiency (weekends, holidays, evening prime-time), uniform allocation of TRPs throughout the daytime;
- Add media activity on another communication channel at the end of the TV campaign for incremental growth of incoming calls.

The recommendations provide an opportunity to increase by 58% the conversion rate compared to the average level in the market. We don't use inefficient channels, time and day intervals, we promptly make the necessary changes in the implementation of the advertising campaign on air.

In the future, we plan to deepen the analysis and evaluate the impact of the media on other channels of the bank's marketing activities: traffic to branches, website traffic, etc.

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Web-Service Management System for Job Search Using Competence-Based Approach

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Abstract. Many different web services for job searching create opportunities for employers and employees, but only a few of them have a focus on IT specialists for firms in different industries. There is a demand on applicants with the required soft and specific subject competencies with minimal time expenditures. The purpose of the research is to develop the architecture of a web service management system for job search at firms using a competent approach according to the international standards of eCF. In present there is no analogue of our web-service management system for job searching using competence-based approach for both employers and employees. The architecture and technical tasks for the participants of our web-based job placement service were developed and described in our research. Web-service includes data which can help to estimate how specific subject competences, age and sex of employees impact on average wage for their vacancies using RStudio packages.

Keywords: data structure, recruitment web-service, required competences, ICT for education.

1 Introduction

Today, in the modern Internet age, there are many different web-based services for job search, in which the number of CVs is significantly higher than the number of vacancies, but only some of them have a focus on IT professionals.

There are international standards for mandatory competencies of IT specialists and no web services that take them into account. So, there is a need to select applicants with the necessary soft and specific subject competencies with minimal time expenses.

After analyzing the existing web services, we were convinced that the advantage of the new web-based job search service is the process of evaluating candidates' competencies according to international eCF and EQF standards that would respond the needs of companies.

The goal of this paper is to develop an architecture for a web-based service for job search based on required competences. The developed web service architecture will allow to select business requirements, user requirements and functional requirements

for the project and submit them as engineering software requirements. It is also necessary to elaborate the development of the service modules in order to create a clear understanding of the structure of each of them separately and mechanisms for interaction with other modules, as well as for the further design of a flexible database architecture. Using data base of web-service employees can estimate how their specific subject competences, age and sex impact on average wage for their vacancies.

The paper has the following structure. The second part examines the literature of the management systems of web-based recruitment services. In section 3 is presented model of employer behaviour and payment using job search web-service. The fourth section has a module structure and software tools. The fifth section describes the experimental data analysis that will be exported from the web service and processed by language R, and the last section concludes.

2 Related Works

Integration of labor market and educational services via the transition from qualification models to mandatory competences of persons help to convert their individual development in professional career [1]. eCF and EQF standards unify competences for labor markets of various EU countries, allows job applicants and employers to act more productively using information about their learning results. The task of the information system UkrESCO is to provide an access to relevant competences for labor market at the moment and update them but does not analyze which types of jobs correspond to required competences [1].

Some persons need advice which type of competence they need in order to get a desirable job, because people with high education and part-time employees more likely to request the advice than low education persons and full-time employees correspondingly [2]. The majority found the advice interesting, relevant and motivating.

Next research in Korea considered the factors of the recruiting websites' service to investigate the relation between the service quality of specialized recruiting websites and user's behavior and perception. It was confirmed that recruiting websites had to adjust their strategic goals by target groups of users because customers' behavior concerning towards web service quality is heterogeneous [3].

Due to stochasticity of Web services for Job Search over the Internet, 'it becomes difficult to select reliable services taking into account non-functional requirements in service-oriented systems' [4]. To avoid the unreliable web services, we need to find several secure service candidates using multiple criteria. After that we can select services based on non-functional requirements. There are services which help to improve job characteristics of employees using web-based continuing learning. The results of the regression model disclosed that 'job control and social support positively associated with employees' attitudes toward web-based continuing learning', but demand on such learning was not significant [5].

Some researches revealed that employees' prefer web service where they receive 'adequate constructive feedback, have a good social support, and feel that the skills and

knowledge they are building are important to society' [6]. Another research study was to evaluate the impact of web-based training on the knowledge and perceived practice of community pharmacy staff. Following the recommendations from adult learning and experimental learning of theoretical frameworks, the proposed training engaged learners in a series of short online educational videos with preknowledge and postknowledge assessment. Training proved to be both effective and essential for pharmacy staff when web-services to ensure they have the necessary skills to be able to do their job well, and online training is an easy and efficient way to provide this training [7]. Paper [8] included next main fields of employers' requirements: soft skills, digital tools, and ability to use web services. In addition to previous skills, employers prefer applicants with project management skills, customer service approach, digital and data base collections, technology implementation in workload, problem solving skills under pressure and experience.

German and Polish firms of different industries need employees with digital competences and skills of business process automation. Core competences for employees in digital economy are 'technical, methodological, social and personal competencies' [9]. To verify how general and specific subject competences have to meet learning outcomes for different firms the following algorithm described in [10, 11, 12] can be used.

Based on the table of analysis of the function of services-analogues (Table 1), we have substantiated the decision on what user requirements and functional requirements should have a web-based job of employment to confirm the competences of students of IT specialties according to eCF and EQF standards and requirements of the IT labor market –sector.

Web-based employment service validates the competences of IT students: future employees, employers (IT-companies) / IT-learning companies and administrators. Therefore, for groups of users, requirements can be divided into three groups.

Table 1. Comparative analysis of management system for employment ('+' means full correspondence, '-' means absence of given characteristics, 'pc' means partial correspondence)

Characteristics	work.ua	rabota.ua	djinni.co	linkedin.com	hh.ua	it-stars.ua	jobs.dou.ua/
1. Scope of IT sector	-	-	+	pc	-	+	+
2. Opportunity to attach own CV	+	+	+	+	+	+	-
3. Filtering information by different parameters	+	+	+	+	+	+	+
4. Section with a robot for students	+	+	-	+	-	-	+
5. Enterprise rating	pc	-	-	pc	pc	-	+
6. Checking of applicants competencies	-	-	-	-	-	-	-

7. Chacking of enterprises information	+	+	+	+	+	-	+
8. Search for matching competencies	-	-	+	pc	-	-	-
9. Integration service of electronic educational resources	-	-	-	+	-	-	-
10. Opportunity of mutual coincidence at the level Employer - Applicant	-	-	+	-	-	-	-
11. Priority selection possibility for vacancies	pc	pc	-	pc	-	-	-
12. Fee payment services	+	+	+	+	+	-	-

On the basis of the above requirements, functional requirements for the employment service were developed. Detailed algorithm of each key functional unit is described in [13], [14].

3 Model of Employer Behaviour and Payment Using Job Search Web-Service

Suppose a risk-averse employer faces a possibility of incurring loss (l) due to absence of employee with necessary competences that will reduce his or her initial profit (W_0). The probability of loss is given by π , and this probability can be reduced depending of the amount (a) that an individual spends on access to job search web-service. We can let $U(W)$ represent the employer's profit in both state 1 (no loss) and state 2 (loss): $W_1=W_0-a$ and $W_2=W_0-a-l$, and employers choses to maximize expected profit: $E=(1-\pi)U(W_1)+\pi U(W_2)$. Taking into account that π is a function of a , FOC for a maximum is therefore:

$$\frac{\partial E}{\partial a} = -U(W_1) \frac{\partial \pi}{\partial a} - (1 - \pi)U'(W_1) + U(W_2) \cdot \frac{\partial \pi}{\partial a} - \pi U'(W_2) = 0 \quad (1)$$

$$\pi U'(W_2) + (1 - \pi)U'(W_1) = [U(W_2) - U(W_1)] \cdot \frac{\partial \pi}{\partial a} \quad (2)$$

This result demonstrates that employer should use job find web-service up to the point at which the expected marginal cost (from reduced profit) of spending one more monetary unit on such activities (the left side of eq.(2)) is equal to the reduction ($\frac{\partial \pi}{\partial a} < 0$) in the expected value of the profit loss that might be encountered when employer lose key employers. Eq.(1) can help estimate maximal amount which employer can spend on job find web-service.

4 Module Structure and Software Tools

The web-based service to confirm the competences of IT students in eCF and EQF standards was decided to develop in two parts, the first is the frontend with which users

interact, the second is the backend part responsible for business logic and user data storage. The system was decomposed into main functional units. Some modules are universal, i.e. they are connected with different groups of agents. (Fig. 1). The interaction between these parts is implemented through the application programming interface (API).

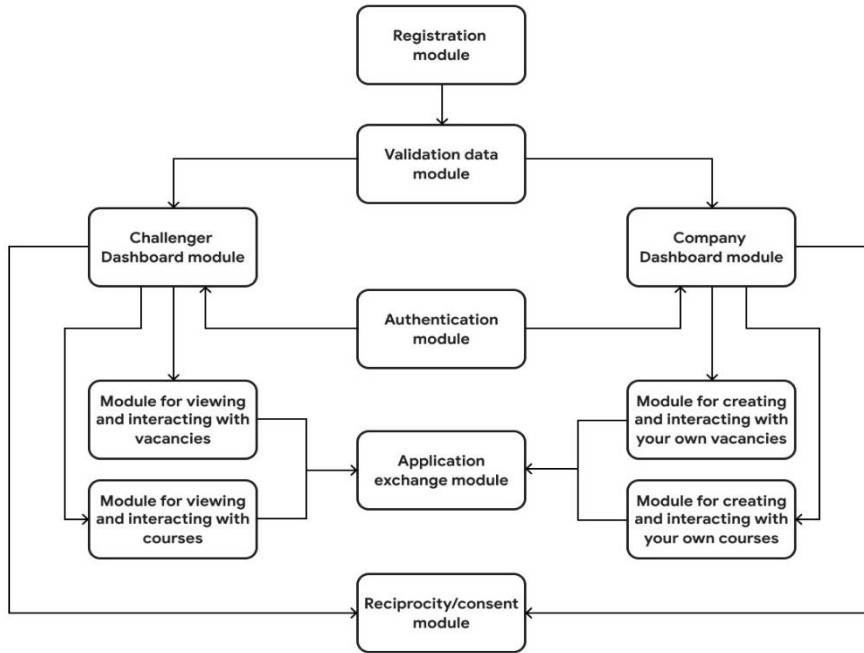


Fig. 1. High-level architecture of the web-service management system for job search

Software requirements include a set of requirements for properties, quality, and software features that determine what will be developed.

There are three levels of software requirements, according to Carl Vigers [15]:

- Business requirements - these are the requirements that determine the purpose of the software product, the goals that must be achieved by the developed software.
- User requirements - these are the requirements that define the list of user tasks that the program must decide, as well as the scenarios for their use in the system.
- Functional requirements are requirements that determine what a software product should do.

Based on the activity diagrams and use cases, the entities were identified and a relational model of the competence-based web service for the employment of IT specialists according to the eCF and EQF competency standards was developed. The model is presented in the form of an ER diagram (entity-relationship diagram) (Fig. 2). Based on all the entities and relationships between them, a database was created.

Validation module contains the main functionality of declared competencies verification of a potential employee by administrators, and also includes a mechanism for checking registered companies and user profiles manually.

Applicant and employer dashboard modules are responsible for the functionality of their own user account and the ability of easy access to other modules that are associated with user profiles. The module for viewing and interaction with vacancies gives an applicant the opportunity to get information about market of vacancies and companies, perform a search by competencies, view detailed data about the vacancy and choose from them.

The module for viewing and interacting with courses will allow the potential employee to obtain information about study programs or courses offered by advanced high educational institutions or IT companies.

Similar modules for employers will give them a possibility to prepare their own vacancies based on the currently required competencies, edit and close them to other agents as well as adding their own competencies to the existing list in the web-service management system.

Application exchange module will allow applicants and employers to determine the supply and demand for competencies, respectively, and also contains the functionality of submitting and processing an application for a study program or course.

Consent module will remove employers' bias against the applicant's identity via opening of full contact information for further communication and cooperation outside web-service based on mutual agreement.

Web-service will ensure the employer with the possibility to reject applicants who do not meet his/her set of required competencies. At the same time, web-service will entitle applicants to cancel proposals that are not interesting to them.

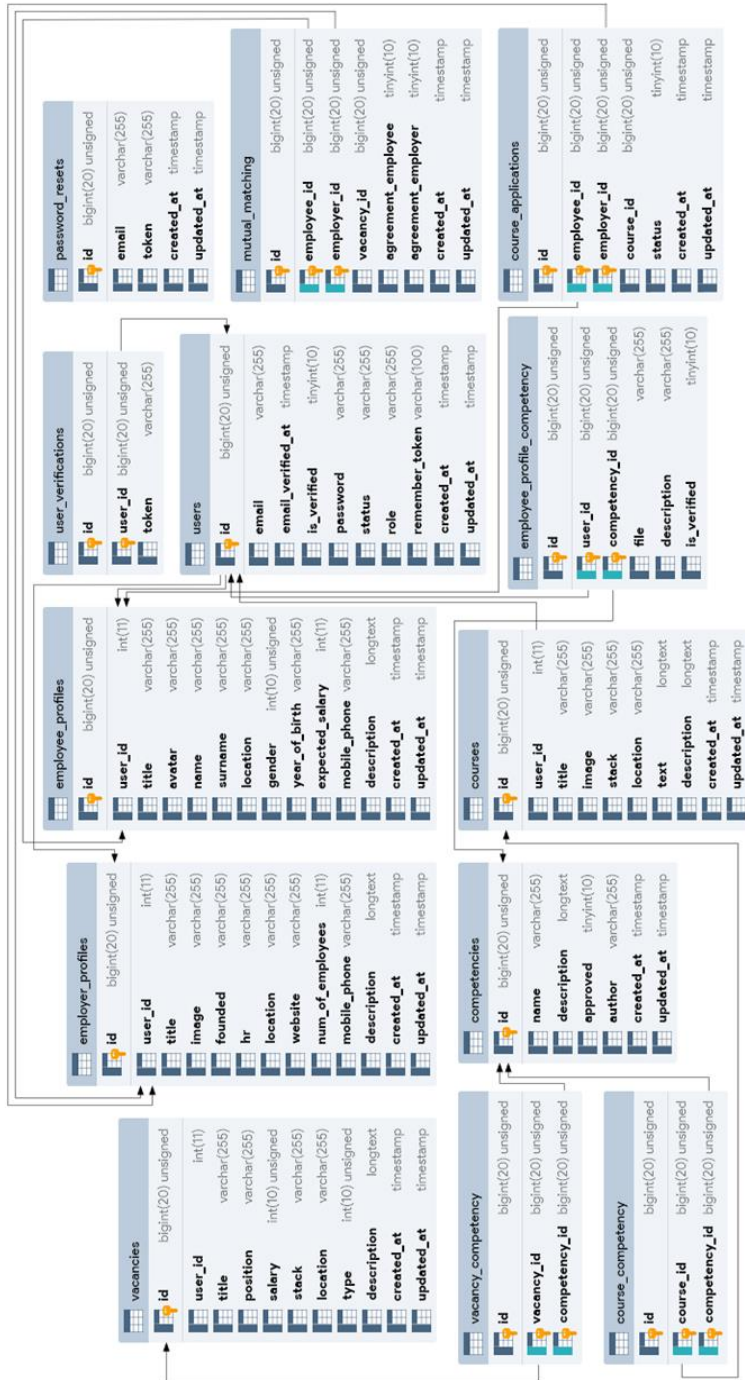


Fig. 2. Entity-relationship diagram

The purpose of e-CF is to provide general electronic competencies that can later be adapted to different business contexts of engineering enterprises, such as e-commerce, e-banking, etc. EQF system that makes it easy compare qualifications from different countries. This is achieved by standardizing the learning outcomes for each qualification to make them more transparent and easier to understand. Thus, EQF supports the cross-border mobility of higher education applicants and workers and promotes lifelong learning and professional development across Europe. The web-based job placement service to validate the competences of IT students at eCF and EQF standards has the following business objectives:

For a potential worker (Fig. 3): to prepare complete demonstration of an applicant concerning the mandatory competencies for the human resource managers on behalf of employers;

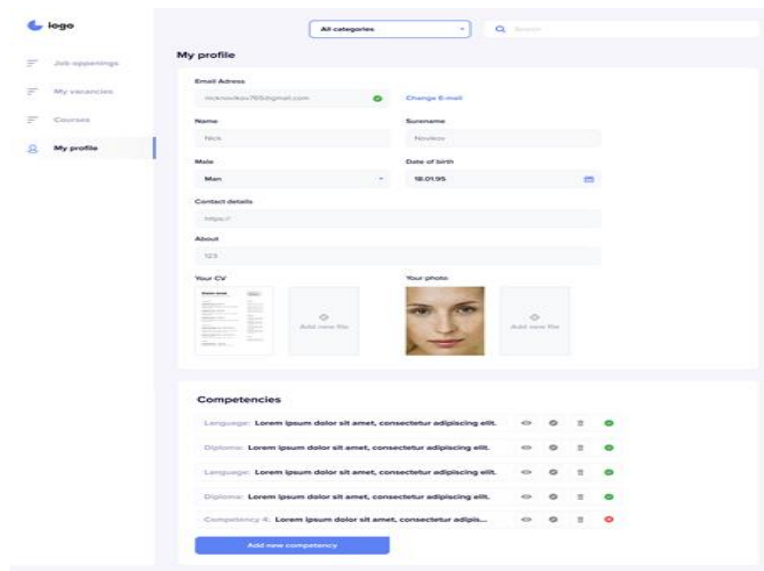


Fig. 3. Potential workers settings of web-service

For the employer: to find quickly the necessary company workers with a structured resume for certified competencies (Fig. 4)

Fig. 4. Creation of new vacancy of web-service

5 Analysis of the Data of the Web-Based Employment Service in R

On the basis of processing data applications from employers about wages, required ("1") and unclaimed ("0") competencies, work experience, higher education, etc. are received. Data export and statistical analysis allows to identify which competencies are in demand and what kind of educational programs are necessary to acquire demanded competences on a job-seeking competence-based website. We will process the data using R package, which allows to quickly process and interpret big data from the web-based employment service.

To do this, we will use the following libraries: `library("dplyr")` - manipulations with data, `library("psych")` - descriptive statistics, `library("lmtest")` - tests for linear models, `library("glmnet")` - methods of relaxation of multicollinearity LASSO + ridge, `library("ggplot2")` - graphs, `library("sjPlot")` - graphical data analysis.

We will add to the R exported from the job-seeking website data in the form of a txt file (number 4 indicates the number of competences that employers need): `h <- read.csv("wagesmicrodata4.txt", sep = "\ t", header = TRUE, dec = ",")`. Next, we estimate the impact of regressors (key competencies COMP1, COMP2, COMP3, COMP4, demanded by employers, sex, age and work experience) to the dependent variable of wages in the following form (where employers considered following competences from eCF standards): (i) Specifying technical tasks; (ii) project management using IT infrastructure, (iii) preparing of business plan, (iv) quality assurance management:

$$WAGE = b_0 + b_1 \cdot COMP1 + b_2 \cdot COMP2 + b_3 \cdot COMP3 + b_4 \cdot COMP4 + b_5 \cdot SEX + b_6 \cdot AGE \quad (3)$$

The results of the calculations are presented in Fig. 5 for different combinations of competences (model 2 is preferable taking into account AIC criterion: the less value the better quality of the model):

	model_0	model_1	model_2
(Intercept)	-0.766*** (0.098)	-0.650*** (0.094)	-0.459*** (0.121)
log(totsp)	1.301*** (0.023)	1.264*** (0.022)	1.219*** (0.028)
brick: 1/0		0.129*** (0.009)	-0.350 (0.193)
log(totsp) x brick: 1/0			0.112* (0.045)
R-squared	0.6	0.6	0.6
adj. R-squared	0.6	0.6	0.6
sigma	0.2	0.2	0.2
F	3194.4	1865.1	1248.6
p	0.0	0.0	0.0
Log-likelihood	422.7	522.4	525.5
deviance	78.9	71.6	71.4
AIC	-839.3	-1036.8	-1041.0
BIC	-822.5	-1014.3	-1012.9

Fig. 5. Statistical estimation of impact of factors on wages

According to the results of estimations, we get that English is more preferable for foreign enterprises than for domestic ones using wage as dependent variable (Fig. 6)

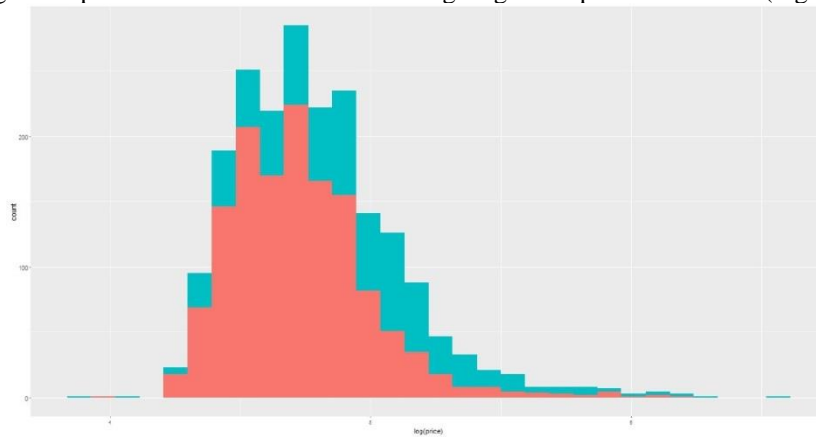


Fig. 6. Statistical estimation of impact of English on wages

Men at these vacancies earn more than women an average for senior positions than for junior ones (fig. 7)

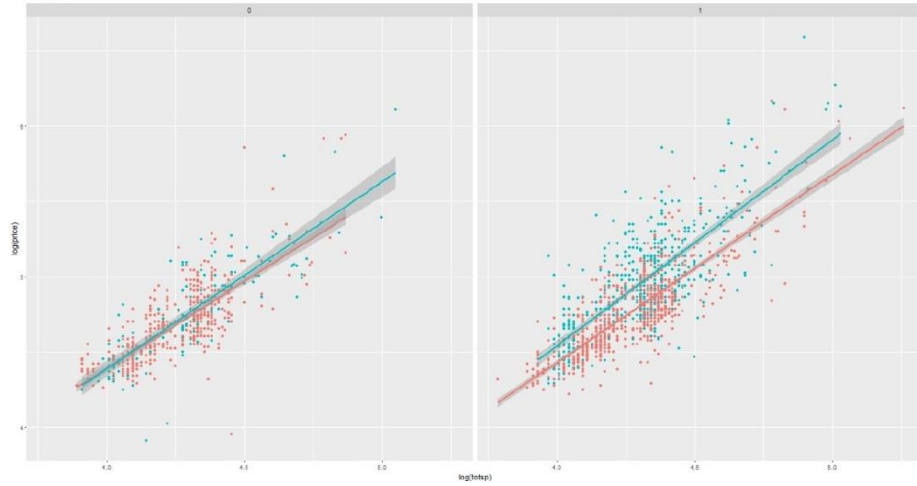


Fig. 7. Graphic estimation of the significance of factors influenced on wages

For the first two main components, we will construct a graph using cluster analysis in R: `> biplot(h.pca,xlim=c(-1,1))`

Fig. 8 reflects part of job applicants who have necessary competences form e-CF pool. Grey color means that data is enough to make such conclusion. Blue color shows that data is more than enough to conclude about per cent of employees with necessary competences. Red color means that data is enough to guarantee such conclusions.

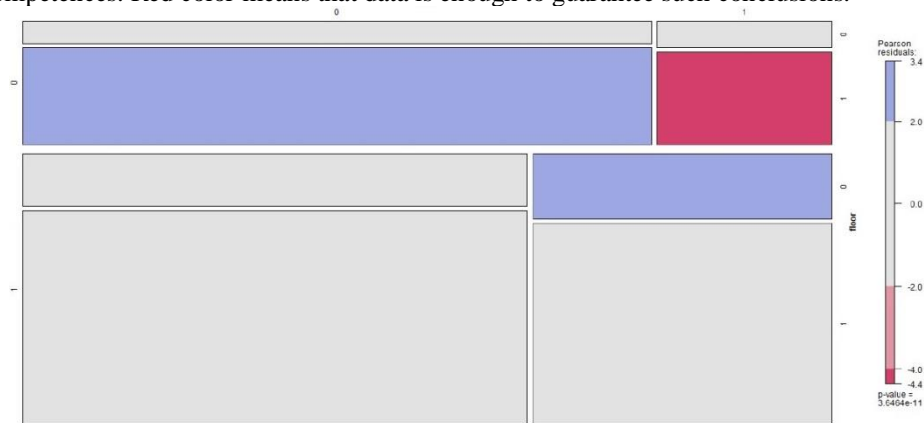


Fig. 8. Mosaic functions to estimate proportions of competences

6 Conclusions and Outlook

The results of the work allowed us to fully form the vision of the project, to distinguish its strengths and weaknesses. Consideration of software requirements has helped to systematize the implementation of the web service and present them unambiguously,

the necessary functions of each group of users and project owners in the form of unambiguous business requirements, and the requirements of the user to submit in the form of a detailed specification requirements. The preformed requirements specification allowed the formation of a relational database model for a web-service management system for job search using competence-based approach. Based on the specification and model of the database, and also taking into account the architectural features of the selected software framework, the description of the necessary functional units within the framework of the program units of "controllers" was carried out.

Data export and statistical processing enabled us to identify which competencies are in demand and for the acquisition of which educational programs are required on a job placement website. Based on the data received from applicants and employers, the benefits of using data processing with the help of RStudio for this service have been demonstrated.

The obtained results are the basis for further program development and testing of the system for assessing the competence of applicants for eCF standards and the selection of vacancies for future employment.

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Information system for controlling transport-technological unit with variable mass

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Abstract. The movement of the system "tractor - transport-technological machine of variable mass" is considered in the context of the movement of the center of mass of the system, given the equality of the internal forces of this system among themselves. Using the obtained dependences, it is possible to determine the effect of changes in the acceleration of the centre of mass of the transport-technological unit with variable mass on the load of the tractor's transmission parts. The tractor control algorithm is synthesized in the rational area of transmission elements loading and a program for its implementation in the field is developed. The developed application is an information system, the purpose of which is to inform the operator of the presence of stress in the transmission's elements of the tractor, which cause it overloading and, therefore, reduce the resource of its parts. If the strength condition for fatigue failure is not met, the operator of the transport-technological unit is offered to change the driving mode to reduce the load on the transmission elements.

Keywords: Controlling, Variable Mass, Information System, Transport-Technological Unit.

1 Introduction

Transport Service System that combines transportation technologies, transport-technological units and organization of technological works is one of the most important components of the agricultural system. Improvement of the Transport Service System is possible using modern information control and diagnostic systems that reduce the probability of error due to the human factor. A number of works are devoted to these problems. The paper [1] considers problems pertaining to operational diagnosis of transport facility operator (driver), describes a basis algorithm of physiological operator's char-

acteristics with the purpose to control his activity during non-standard situations. Introduction of a system activity with use of modern satellite technologies allows to lower transportation costs, to increase efficiency of use of agricultural machinery is considered in the work [2].

The issue of designing the machine tractor movement trajectory is relevant today because its optimization significantly reduces the transport costs [3]. Comparative study of the usability of directional commands for two different conceptions of agricultural machinery is conducted in the work [4]. The clarification of the normal reactions distribution between the axles allows to choose more rational forces distribution between the axles. It has a significant impact on the stability against skidding and the wheeled tractor braking effectiveness. [5] The dependence of the influence of vertical accelerations on the dynamic loads on the axle of the tractor front and rear axles is determined in the article [6].

However, research on the use of tractors on the transport and technological agricultural operations were identified unsolved problems, which include: dynamics of a variable mass aggregate, energy saving [7], formation of system properties of the unit elements [8]. The general principles of forming the time to failure due to deviations from the nominal values of external perturbations do not justified [9, 10]. The problem of dynamics of transport-technological unit with variable mass is not solved in terms of their energy efficiency and performance [11].

2 The acceleration of the centre of mass as a quantity forms the energy of the movement of the unit

The movement of the system "tractor - transport-technological machine of variable mass" can be considered in the context of the movement of the centre of mass of the system, given the equality of the internal forces of this system among themselves.

Then, it can said that the movement of the centre of mass of the given system at each moment of time is equivalent to the movement of a material point with a mass equal to the mass of the system at a given moment of time, which is affected by a force equal to the resulting forces applied to the system:

$$\frac{d(m' \cdot v_c)}{dt} = F_{\Sigma}, \quad (1)$$

where v_c - the velocity of the center of mass of the system;

m' - the mass of the system at a given time (quasistatic mass);

F_{Σ} - the main vector of the system of forces, which is applied to the unit.

Multiplying equation (1) by the displacement of the centre of mass of the system, which is caused by a change in the mass of the transport-technological unit dS_{var} and its displacement in space dS_{con} over the considered time interval:

$$\frac{d(m' \cdot v_c)}{dt} (dS_{con} + dS_{var}) = F_{\Sigma} (dS_{con} + dS_{var}), \quad (2)$$

Opening the brackets and taking out the quasistatic mass beyond the differential sign, got:

$$m' \frac{dv_c}{dt} dS_{con} + m' \frac{dv_c}{dt} dS_{var} = F_{\Sigma} dS_{con} + F_{\Sigma} dS_{var}. \quad (3)$$

Considering that $dA_{con} = F_{\Sigma} dS_{con}$, and $dA_{var} = F_{\Sigma} dS_{var}$, it can be written:

$$dA_{con} = m' \frac{dv_c}{dt} dS_{con}; \quad (4)$$

$$dA_{var} = \Delta m \frac{dv_c}{dt} dS_{var}. \quad (5)$$

where Δm - changes in weight of the transport-technological unit.

The value $A_{con} = m' \cdot a_{unit} \cdot S_{unit}$ determined by dependence (4) represents the work required for the self-movement of the transport-technological unit in space at a distance S_{unit} with acceleration a_{unit} , which is determined according to the tractor's traction balance.

Value $A_{var} = \Delta m \cdot a_c \cdot S_c$ - the work spent by the unit on moving S_c the center of mass of the unit with acceleration a_c as a result of changes in its mass.

Thus, it can be argued that there is a direct proportion link between the work expended by the unit, and the acceleration of the center of mass. Therefore, using known definition of safety margin and accepting $a_{unit} \rightarrow 0$, it can be obtained the condition of fatigue strength of transmission's parts, taking into account the acceleration of the center of mass a_c at a certain displacement S_c

$$a_c \leq \frac{l \cdot W_p^2 \cdot K_F^2 \cdot K_d^2 \cdot \tau_{-1}^2 \cdot \sigma_{-1}}{3,4 \cdot G \cdot J_p \cdot \Delta m_{unit} \cdot S_c \cdot (K_{\sigma}^2 \cdot \tau_{-1}^2 + K_{\tau}^2 \cdot \sigma_{-1}^2)}. \quad (6)$$

Using the obtained dependence, it is possible to determine the effect of changes in the acceleration of the centre of mass of the transport-technological unit with variable mass on the load of the tractor's transmission parts.

3 Ensuring the fatigue strength of transmission elements, taking into account the energy losses of the unit

The strength of materials under impact loads variables characterized fatigue curve. It presents the link between the highest values of variable cyclic stress in a material σ_a and the number of cycles these stresses N to destruction.

When building the dependence of the number of cycles of alternating strength in the material of the part to destruction from changing them amplitudes in logarithmic coordinates $\lg \sigma_a - \lg N$, the fatigue curve is represented like a broken line, the left branch of which is inclined to the abscissa axis at an angle, and the right branch is conventionally assumed horizontal due to its small inclination in reality and propagation to such a large number of load change cycles, which is assumed to be rare due to the limited service life of the tractor's transmission.

The common form of the fatigue curves for various materials and samples allowed us to use their analytical expression and compare the characteristics of fatigue strength not by comparing the curves as a whole, but by comparing individual numerical indicators.

Stepped dependency is the most common analytical description of a fatigue curve:

$$\sigma_a^m \cdot N = A, \quad (7)$$

where A – constant.

For the discrete repeatability of stress cycles in the part material, the mathematical expression of the linear accumulation of fatigue damage has the form:

$$\sum_{i=1}^r \frac{n_i}{N_i} = L, \quad (8)$$

where n_i - is the number of cycles with the amplitude of the i -th level, during the process; N_i - the number of cycles with amplitude of the i -th level, with continuous action of which the material is destroyed; r - the number of strength levels, covers the entire range of changes during the process; L - indicator of damage.

According to this cumulative hypothesis, destruction in the material occurs when $L = 1$. However, numerous experimental researches show that the indicator of damage L during breakage is different from 1. Moreover, formula (8) becomes:

$$\sum_{i=1}^r \frac{n_i}{N_i} = a. \quad (9)$$

The value a depends mainly on the material of the part and partially on the parameters of the spectrum of stress amplitudes. In this regard, for calculating the equivalent stress, the condition for summing the damaging effects of various cycles, while maintaining

linearity, is attributed to a certain calculated fatigue curve that differs from the initial degree in terms of degree m .

When calculating the absolute durability of accounting for such an amendment is very significant. When calculating the comparative durability, the spread of the indicator a in the usual range for steels (0,8 ... 1,4) leads to small differences in the degree of the calculated fatigue curve from the real one.

Thus, it can be concluded that the use of a relation in comparative calculations does not give large errors even when the parameters of the spectrum amplitude of the compared modes will differ significantly.

We introduce two modes of transmission elements loading: for the movement of a transport-technological unit of constant and variable masses. Then, for the moment when the accumulated damage in the metal is equal, we get:

$$L_{cons} = L_{var}, \quad (10)$$

and taking into account expression (8) it can be written:

$$\sum_{i=1}^{r_{cons}} \frac{n_{i\ cons}}{N_i} = \sum_{i=1}^{r_{var}} \frac{n_{i\ var}}{N_i}. \quad (11)$$

Since the calculation of the transmission elements loading is carried out according to the stresses, which are defined in accordance with the law of fatigue failure, for cycles of any level, it can be written:

$$\sigma_{ai}^m \cdot N_i = \sigma_{-1}^m \cdot N_0, \quad (12)$$

where σ_{-1} – the endurance limit.

Then

$$N_i = \left(\frac{\sigma_{-1}}{\sigma_{ai}} \right)^m \cdot N_0, \quad (13)$$

and from the expression (11):

$$\sum_{i=1}^{r_{cons}} \frac{n_{i\ cons}}{\left(\frac{\sigma_{-1}}{\sigma_{ai}} \right)^m_{cons} \cdot N_0} = \sum_{i=1}^{r_{var}} \frac{n_{i\ var}}{\left(\frac{\sigma_{-1}}{\sigma_{ai}} \right)^m_{cons} \cdot N_0}. \quad (14)$$

Taking into account the fact that, for a given part, the values σ_{-1} and N_0 are independent of the load conditions, expression (14) takes the form:

$$\sum_{i=1}^{r_{cons}} n_{i\ cons} \sigma_{ai}^m = \sum_{i=1}^{r_{var}} n_{i\ var} \sigma_{ai}^m. \quad (15)$$

Let the transport-technological unit carry out the technological process with a certain value of the expended work A , and the work to a comparable degree of damage to the material is equal A^* .

Then the number of cycles of each observed level until the moment of comparison on the compared operating modes of the transport-technological unit can be expressed through the results of experimental studies in the form:

$$n_{i\ cons} = n'_{i\ cons} \frac{A_{cons}^*}{A_{cons}}, \quad (16)$$

$$n_{i\ var} = n'_{i\ var} \frac{A_{var}^*}{A_{var}} \quad (17)$$

where the dash indicates that the corresponding value obtained on the basis of realized process.

Substitute (17) in (16):

$$\frac{A_{cons}^*}{A_{cons}} \sum_{i=1}^{r_{cons}} n'_{i\ cons} \sigma_{ai}^m = \frac{A_{var}^*}{A_{var}} \sum_{i=1}^{r_{var}} n'_{i\ var} \sigma_{ai}^m. \quad (18)$$

Then the ratio of work on these modes:

$$\frac{A_{cons}^*}{A_{var}^*} = \frac{A_{cons} \sum_{i=1}^{r_{cons}} n'_{i\ cons} \sigma_{ai}^m}{A_{var} \sum_{i=1}^{r_{var}} n'_{i\ var} \sigma_{ai}^m}. \quad (19)$$

The resulting expression can be considered as the coefficient of equivalence of the work spent on moving the transport-technological unit with constant and variable masses. Denoting it by the letter k_e , will get:

$$A_{cons}^* = k_e \cdot A_{var}^*. \quad (20)$$

The given stress of the steady state σ_{np} , equivalent to that in the unsteady mode, is determined from the dependence of the form:

$$\sigma_{np} = \frac{1}{\sqrt[m]{a}} \sqrt[m]{\left(\frac{1}{N_0}\right) \cdot \sum_i (\sigma_i^m \cdot n_i)}. \quad (21)$$

Then, the safety margin can be determined from an equation of the form:

$$n = \frac{\sigma_{-1}}{\sigma_{np}} = \frac{\sigma_{-1} \cdot \sqrt[m]{a}}{\sqrt[m]{\left(\frac{1}{N_0}\right) \cdot \sum_i (\sigma_i^m \cdot n_i)}} \quad (22)$$

4 Experimental study

To test of the transport-technological unit with variable mass based on the KhTZ-17221 tractor as part of an aggregate with a machine for applying liquid organic fertilizers MZHT-10, the experimental researches of the overload signaling device of the tractor's transmission unit were carried out, developed on the Android platform. The developed application is an information system, the purpose of which is to inform the operator of the presence of stress in the transmission`s elements of the tractor, which cause it overloading and, therefore, reduce the resource of its parts. The main application window consists of four main zones (Fig. 1).



Fig. 1. General view of the application window for controlling transport-technological unit with variable mass

The top part of the main application window is a menu for adjusting the view of the transmission`s elements and the selection of the constituent elements of a transport-technological unit with the variable mass. When the model of tractor and agricultural

machine are selected, the program independently, using the existing database, generates mass-geometric indicators of the transport-technological unit for the future calculations.

The second (middle) part of the main application window displays the load distribution in the transmission's elements. Because of the smartphones architecture, the visualization of transmission elements is a set of frame-by-frame animation of load redistribution.

Second (middle) part the main window the programs are designed for visualization distribution load elements transmission installation. Given features architecture smartphones visualization elements transmission is a set of time-lapse animation redistribution loaded.

The third part of the main application window displays basic information about the values of stresses caused by the torque in the transmission elements, and the value of the cycles to fatigue failure.

Moreover, if the stress value exceeds the permissible limits, and the value of the residual number of cycles is critical, the fourth part of the main application window (information panel) changes its color from green (see Fig. 1) to orange (Fig. 2), and the inscription "Continue to work on this gear" is replaced by the inscription "Need to change gear" (see Fig. 2).

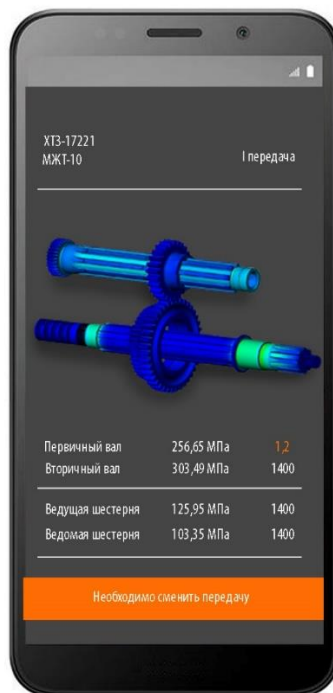


Fig. 2. General view of the application window for controlling the transport-technological unit with variable mass when the transmission is overloaded

The developed application uses input data from its own database (the mass of the transport-technological unit, transmission ratios and engine characteristics), as well as acceleration of the centre of gravity along three coordinate axes.

To attract the operator's attention, when the elements of the transmission are overloaded and the operation mode needs to be changed, an audio signal is given, and it turns off only after the transmission loading mode returns to rational.

Conclusions

According to the results of a comprehensive analysis of the energy losses of the transport-technological unit with the variable mass, when performing the technological process, the concept of a systematic approach is substantiated, which is the scientific novelty of the study, increasing the operability of the unit, which, unlike the known ones, is based on the proved statement, ensuring a minimum of energy losses on oscillatory the motion of the center of mass.

The tractor control algorithm is synthesized in the rational area of transmission elements loading and a program for its implementation in the field is developed. The principle of the application is based on the algorithm and use an acceleration sensor built into the phone. Because the application is designed on an open operating system Android, it can be said that it is available for almost all existing smart phones.

The main condition for the correct functioning of the program is the location of the phone so that at least one of the axes of its accelerometer coincides with the direction of movement of the transport-technological unit with the variable mass.

Obtained results can be extended and used on other types of vehicles. In the future, it is planned to expand the amount of source data for the application, which will increase the accuracy in determining the optimal modes of operation.

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Development of information system to model cyclic fluctuations of economic time series

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Abstract. Decision making in the economy demands tools to find the most effective, cost-affordable, and optimal solutions. Besides, there is a high necessity to have possible solutions not for tactic needs but for strategic as well. Business and economic analysts of all levels of economic management are eager to put up the user-friendly software, apps, or solutions to support their analytic and forecasting attempts. In the epoch of the claimed Industry 4.0, rapid digitization and on-line of recent quarantine events, the information systems, and any computer support is the best possibility and treasure. This paper is devoted to the idea of possible computer support for the analysis and forecasting of economic dynamics. Particular attention is paid to the time series modelling and detecting of its cyclic component. The majority of economic time series have the seasonality or other cycling inside of its dynamics, that could dramatically pervert the linear trend forecast or any other determinate direction of the trend. The proposed information system is quite user-friendly but the low error way provides a potential user with the tool of cyclic component forecasting. The methodology is grounded in the Assimakopoulos cyclicity filter. The case of Denmark's GDP quarterly since 1995 is presented to test and confirm the system's effectiveness in acquiring knowledge about the dynamics of the economic system. The sufficient accuracy of the implemented forecasting methods is presented.

Keywords: Information system, Economic cycle, Assimakopoulos approach.

1 Introduction

A large proportion of open databases for the analysis are represented in the time series view. There is often a need to analyze the main components of the time series: the trend, seasonal, cyclic, and random components. The presence of each component is explained by different reasons. The trend component that determines the direction of process change is most often analysed in the time series. Its presence is usually explained by demographic or technological factors. There are numerous opportunities for trend modelling, in particular, the regression approach that allows different shapes of a trend component modelling: linear, quadratic, exponential, and so on. It is also

possible to detect the magnitude of the trend by using certain smoothing methods: the sliding average method, exponential smoothing [14], double Brown exponential smoothing, triple Brown exponential smoothing, Holt-Winters' model [7].

It is no less common to exploit cycles and seasonal variations that show periodic changes over a certain period. For example, in agriculture and demography the modelling of monthly or quarterly fluctuations during the year, daily fluctuations during the week, and so on are in the scope. Some methods have been developed to highlight seasonal variations, including the Holt-Winters' seasonal models and the seasonality index model. Econometrists often model seasonal fluctuations by adding some dummy variables to the regressions. It allows determining the effect of each season on the variable under study.

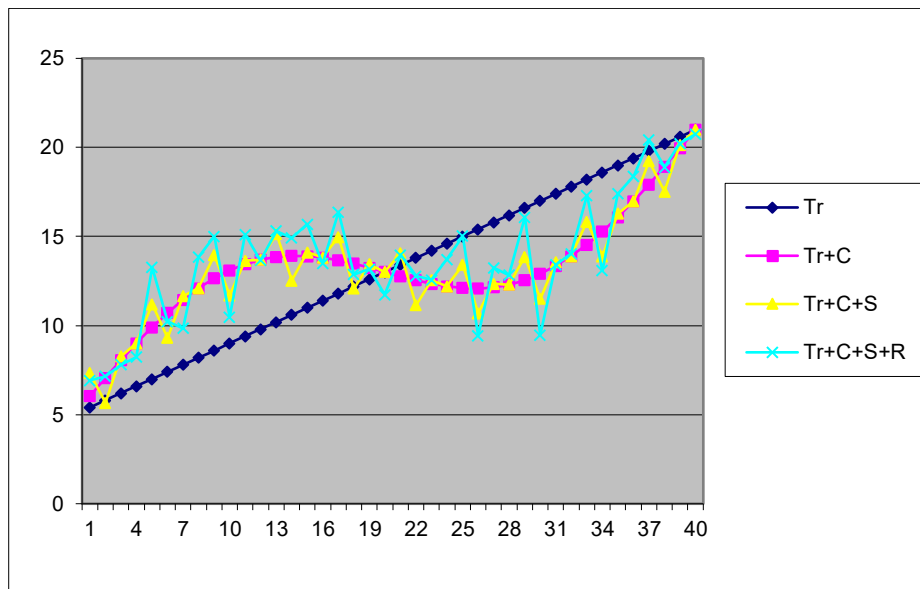


Fig.1. Time series components. Source: authors' compilation.

As a rule, all parts of the time series that are not included in the trend or seasonal component are referred to as the random component. There are some possibilities for creating models for random component analysis, in particular ARMA models [6]. However, researchers do not always carefully examine how this random component is formed. For example, if a variable under study is affected by weather, which is currently very difficult or impossible to predict over a long period, then it is referred to as a random component. It also might include the effects of the cyclic component. This is uncertainty happens because, in practice, analysts rarely work with enough long time series reasoning by the significant changes in the methodology for collection and

processing economic data. However, if such a series still exists, then it is necessary to detect a cyclic component (Fig. 1).

In practice, the cycle extraction from the trend causes considerable difficulties caused by the interconnections. The trend shows a long-term change direction. Whilst the cyclical component is a rhythmic fluctuation of indicators by a certain value, which can be observed only for a rather long period. One of the approaches to isolate cyclic sequence fluctuations is the Assimakopulos cyclicity filter [1]. It is not mathematically complicated, so it can be easily programmed and is most practical to use, although relatively little known.

The purpose of this paper is to propose an information system that based on an imported database could eliminate the cyclical fluctuations in time series and simultaneously detect both the magnitude of such fluctuations and other components of the series.

Structurally, the article consists of the following sections. The literature review presents an analysis of publications with methods for identifying the cyclic component in different fields, identifying their advantages and disadvantages. The methodology section describes the formal rules for allocating cyclic components in time series. The following section demonstrates the ability of an information system to split the time series into components. Finally, the last section provides conclusions.

2 Related works

The literature review on the cyclic component detection in the time series is quite vast. However, the main idea of this paper is to match the research gap in the studies of time series in the economic and social fields, along with the literature on the IT systems in the economy, particularly to put in the forecasting tools topic.

A significant problem in the economic situation forecasting and analyzing is to correctly identify the beginning of each phase of the cycles. This issue is still causing considerable debates among scientists because even under the modern development of statistical science, different researchers differently determine the presence of a new phase of the cycle. At present, there is no clear interpretation of the change in cycle phases, and therefore the cycle length. The latter magnitude is generally associated with the prime problems in the cycle formalization. Since even in retrospect there is no clear interpretation of the start and endpoint of the cycle: they are hardly determined.

Of course, the current state of issues provokes the necessity to develop a model for determining the length of cycles and the time of their phase change. There were attempts to develop such a mechanism using Markov chains [31]. Nevertheless, such a mechanism, on the one hand, is rather bulky and difficult to use, and on the other hand, has no restrictions on cycle phase changes, which makes it impossible to appeal to the classical definition of the cycle.

In economics, the economic cycle refers to fluctuations with a fixed period. The most important types of cycles [27] are:

- Kitchin warehouse cycle, 3-4 years long;

- Juglar fixed-investment cycle of 7-11 years;
- Kuznets infrastructural investment cycle (15-25 years);
- Kondratiev wave of 45-60 years;
- Forrester cycle of 200 years.

The logic behind the proposed cycle lengths is determined only by the authors' understanding of the time it takes to change a particular product, production facility, or economic model. Still, it should be noted that all of these developments were based on data from the late XVII - early XX centuries. Though, the speed of economic change and new technologies launch has completely changed the idea of how the phases of the cycle change, what its real length is. Indeed, in the XVIII-XIXth centuries governments did not inspect the effects of cyclical fluctuations, and consequently did not respond to them. Then it says about the relative purity of scientific analysis of the crisis length. Yet, as early as the XXth century, following the Great Depression, governments began to use different mechanisms to avoid or eliminate the crisis. Such attention to crisis analyses could not affect the real economy and the behaviour of people who changed their expectations about the frequency of crisis and their devastating consequences. Although it did not lead to the complete abolition of the economic crisis, it has significantly changed the incidence and new expectations of people. In particular, if people previously feared crisis due to temporary loss of life and a rise in the cost of living, then today, the population expects only extremely dire crisis on a global scale with the devastating force like the 2020 pandemic coronavirus has shown.

Also, it should be understood that globalization is a process of synchronization in crisis phenomena. The paper [17] analyzes the level of economic growth synchronization in 185 countries. It was shown that a high level of synchronization was observed from 1990 to 2011. During this period global shocks accounted for about 77% of GDP dispersion in developed European countries. At the same time, regional shocks have played a greater role in the CIS, Asia, Africa and the Middle East. The results indicated a higher level of synchronization in industrialized countries. Also, it should be noted that according to [17] the global financial crisis led to an increase in a global synchronization of economic growth, but the level of synchronization decreased at the beginning of recovery.

Accordingly, a particular problem of long-term forecasting is the allocation of cycles of different lengths. If all the cycles were of a predetermined length, if their objective manifestation was not impeded by numerous factors, then the possibility of mathematical determination of groups of cycles could be clear and simple. In fact, to determine the cycles of different lengths the researcher needs a sufficient number of observations. For example, to determine a cycle of 45-60 years (Kondratiev long waves), a series of at least 200-300 observations should be analyzed. Since the cycles are allocated with annual data, it is necessary to have the dynamics of some economic process at comparable prices for 300 years. That is a statistical challenge of any country in the world.

Thus, at the present stage of statistics, it is impossible to determine cycles with a large wavelength by mathematical methods alone. Having only more or less reliable and comparable observations over the last 100-120 years, one can speak of the alloca-

tion of small and medium cycles. However, it should be noted that the required statistics only exist in some countries. The geopolitical redistribution of the 1990s, the creation of new states, make it impossible to comprehensively analyze and test any method on real data.

This problem is not limited to economics. For instance, cyclical fluctuations are present in the climate change on the planet. Nevertheless, due to the destructive activities of mankind, increasing the carbonation of the economy, the impact of cycles has significantly decreased compared to the global temperature increase trend, which does not allow it to be distinguished by standard econometric methods. Global warming and climate change have recently led to environmental, physical and medical consequences, including extreme weather events. Compared to 1850, the average temperature in the Northern Hemisphere has become higher by about 1.4 degrees Celsius, and in the Southern Hemisphere by 0.8 degrees Celsius [23]. Despite numerous agreements to limit atmospheric emissions, for the first time in four years, CO₂ emissions increased in 2017 leading to atmospheric concentrations of up to 403 ppm compared to the pre-industrial level of 280 ppm. Over the past half-century, emissions have grown exponentially and temperatures have risen linearly [28].

Afterwards, there is an assembly of studies dedicated to the cyclic fluctuations modelling in the ecosystems to forecast chaos state (i.e. [3, 13]). Mathematical models have shown that species interactions can produce chaos. However, the field evidence of chaos in natural ecosystems is still quite singular. In [3] it had shown that natural ecosystems can sustain continued changes in species abundances and that seasonal forcing may move forward these non-equilibrium dynamics to the edge of chaos. The next set of published studies is considering the fluctuations and cycling in time series analyses implementing it to the ecology [4-5], macroeconomics and investing [12, 25, 29], demographics and social economics [20, 22, 24]. Most of the studies are devoted to modelling short-term fluctuations in the presence of seasonal and long-term patterns, dealing with time-varying confounding factors and modelling delayed ('lagged') associations between exposure and outcome [4].

The major part of researches determines the cyclic component as regular or periodic fluctuations around the trend, excluding the irregular component, revealing a succession of phases of expansion and contraction [16]. The cyclical component can be viewed as those fluctuations in a time series, which are longer than a given threshold, e.g. 1½ years, but shorter than those attributed to the trend [26]. The best example is a business cycle, which typically lasts several years, but where the length of the current cycle is unknown beforehand, like the famous Canadian lynx data – the number of lynx trapped each year in the McKenzie river district of northwest Canada (1821-1934). These clearly show a periodic population cycles of approximately 10 years. The cycles are not of fixed length – some last 8 or 9 years and others last longer than 10 years [30].

At the same time, the realisation of time-series analyses for the economic modelling is not exhausted just with tools of R, Eviews, Excel and other known software. More and more companies are trying to support their analysts with quick, simple and effective software that able to be helpful even for the person without deep econometrics education, like logistics, marketing or production managers etc. Within the artifi-

cial society, launching Industry 4.0 and the new era of robotization, there is a higher demand on the computational intelligence that would be able to produce friendly interface software with the application of the complicated but quite effective fuzzy-logic-based computing, econometrics modelling, particularly time series modelling, neurocomputing[19]. The business struggles to solve complex computational problems in the economic systems by using conventional mathematical methods but in a friendly way for a broad group of managers and decision-makers [2, 9, 21].

Highlight, that detecting of cyclicity is highly important for the economy. The nature of the cyclicity of economic variables or political decisions is inherently linked to the concept of the business cycle [11]. The simplistic idea of cyclicity research is to isolate cycles from the overall economic dynamics and analyze their dynamic relationship within the processes under study. Thus, the problem of correct allocation of the cyclical component of economic development is central to such studies. Besides, this problem has been and remains one of the most important in economic theory, as evidenced by the broad list of Nobel laureates who have made significant contributions to the development of the problem (Finn Kidland and Edward Prescott, Robert Engle and Clive Granger, Christopher Sims and Thomas Sargent) [8].

From the point of economic policy decisions, pro-cyclical discretionary economic decisions stimulate the phases of the economic cycle - in case of uplift they stimulate economic activity, in case of recession they cool the economy [18]. A pro-cyclical economic policy increases the amplitude of business cycle fluctuations. Acyclic economic policy does not affect cycle parameters. Counter-cyclical policy cools the economy in the face of overheating trends and stimulates the recession phase. Determination of cyclicity characteristics in terms of business cycle theory and economic politics is not always the same. If government spending increases in the business cycle growth phase and falls in the fall phase (positive correlation), then we have an example of pro-cyclical policy on both approaches. If, for example, to take into consideration the central bank's discount rate, then raising it during an economic upturn and lowering it during a recession (positive correlation) we will formally consider pro-cyclical behaviour, but in terms of monetary policy, we are dealing with counter-cyclical measures [10].

To highlight the cycles of an economic process, the first question that needs to be answered is the trend characteristics of the dynamic process. Choosing a rational forecasting strategy is one of the fundamental problems in any sector of the economy. The arsenal of economic cybernetics methods contains a large number of various methods of economic dynamics (time series) analysis which distinguishing feature is considerable computational complexity and, as a consequence, the impossibility of practical application without the use of modern software. The purpose of economic dynamics analysis is the conceptualization of a comprehensive computer system to support the forecasting ability. Mostly the researchers and economists are eager to obtain qualitative conclusions about the nature of the system behaviour to predict it and then use the results in the management of the economic system. Thus, the conceptual components of the complex economic system analysis and forecasting are monitoring, forecasting and subsequent management. This reflects the main stages of economic and mathematical modelling (research, forecasting and management of the economic system)

and provides an integrated approach to the study of the economic system dynamics and the use of its results [15]. Hence, the example of one of the solutions to the indicated problem is presented in this paper.

3 Methodology

As already mentioned, the allocation of cyclicity of time series fluctuations is an important practical task. First, it is necessary for macroeconomic research, because it is based on the analysis of the current economic cycle phase. Moreover, it enables to formulate an appropriate anti-cyclical or pro-cyclical government policy. Secondly, it is no less important to identify cyclical fluctuations for microeconomic modelling, in particular for the company sales analysis. At the same time, analysts often face a certain problem, which is the lack of long time series. This is due to the life cycle of the company, a particular product, accounting software, and so on. In any case, only a few firms can boast of having such long time series on which it would be realistic to distinguish cyclical fluctuations. Therefore, the model that allows this to be done with the least amount of observations, especially in automatic mode, should be valued by analysts quite highly.

In the literature review, it was pointed out that in fact there are not many effective models used to detect cyclic oscillations, and therefore the choice is narrowed to those that are able to work with short time series. We have chosen the Assimakopoulos filter, which independently determines the length of the cycle on the basis of calculations, and makes it possible to determine the cyclic component of the time series, using only the initial data series.

To present the information system we consider the Assimakopoulos method for allocation of cycles in the economic time series. The idea behind the cyclic isolation method is to eliminate cyclic effects based on the so-called θ -transformation. Such a filter can eliminate cyclic fluctuations of any length. Let the momentary trend in time t be equal

$$tr_t = y_{t+1} - y_t, \quad t = \overline{1, T-1}.$$

The new sequence is built by the rule:

$$\tilde{y}_t = \begin{cases} \frac{y_{t+1} + y_{t-1}}{2}, & \text{if } |tr_t - tr_{t-1}| > 0 \text{ and } |tr_t - tr_{t-1}| = \max_{k=2, T} \{|tr_k - tr_{k-1}|\}, \\ y_t, & \text{in other cases.} \end{cases}$$

It should be noted that this method does not apply to the linear trend series. We assume that the time series is believed to have a "pyramidal" structure. It is based on a straight line that refers to the simplest long-term trend. This line is superimposed on cyclical effects, starting with the longest end and ending with the shortest. In other words, the cyclic effects are superimposed on the trend line in a strictly decreasing order, depending on their length. This reasoning is consistent with the assumption that small cycles exist as part of long waves. Finally, the pyramid ends with the imposition of a random component.

The use of θ -transformation first eliminates the time series of the random component, then the shortest cycle, and ends with the trend selection. To use θ -transformation to eliminate cyclic effects, we enter θ -index:

$$\theta_p = \frac{100}{\max_{t=1,T} y_t - \min_{t=1,T} y_t} \max_{t=2,T-1} \{|tr_t - tr_{t-1}|\}$$

Let's consider step by step the structure of the method iterations:

Step 1. Calculate the two additional observations to be added at the beginning and at the end of the time series.

Step 2: Initially estimate the length of the longest cycle that appears in the time series.

Step 3. Implement θ -transformation for a new time series derived from the original row by adding new elements in step 2.

Step 4. Calculate θ -index for each newly received time series.

Step 5. End the process when the time series θ_p -index refers to the largest cycle estimate (as initially estimated in step 2). Thus, the time series obtained contain the trend of the initial time series.

Then a regression on the first and last n observations is constructed to obtain additional observations. Most commonly researchers use $n = 5$.

It should be noted that the above method eliminates the time series of all cyclic fluctuations whose length is less than selected in step 2. It cannot be guaranteed that the maximum possible cycle length will be selected.

It has been practically found that there is a relationship between the θ_p -index and the length of the longest cycle, which can be determined from the time-series graph. It has been shown that the l_k length of cycles using θ -transformation disappear if $\theta_p \leq k$. The relationship between θ_p and k for monthly data is the following:

- $\theta_p = 1$, the length of the eliminating cycle is equal to 5 (period of 5 months);
- $\theta_p = 0.1$, the length of the eliminating cycle is equal to 12 (seasonal cycles);
- $\theta_p = 0.02$, the length of the eliminating cycle is equal to 45-60 (period of 4-5 years);
- $\theta_p = 0.007$, the length of the eliminating cycle is equal to 80-125 (period of 7-10 years).

The above method can be widely used in forecasting a variety of economic information. It should be noted that generalization of known techniques can (as in the case of exponential smoothing) improve the accuracy of forecasts.

Thus, when running the program for the initial sequence (which is the database), the maximum and minimum values are calculated. Further, based on a simple linear regression (usually taking the step $n = 5$), the additional values are calculated having 0 and $k + 1$ positions, where k is the number of database elements. Based on the difference between the k -th and $(k-1)$ -th element of the sequence, the trend is calculated. Based on the difference between the i -th and $(i-1)$ -th value of the trend, the difference

in the trends is counted. One can select the largest value of the trend difference by the module. Next, it is appropriate to use the formula that calculates theta-index:

$$\begin{aligned}\Theta_p &= \frac{1}{\max L - \min L} \cdot \max_{i=2}^{N-1} 100 \cdot \{|Tr_i - Tr_{i-1}|\} \\ &= \frac{1}{\max L - \min L} \cdot \max_{i=2}^{N-1} 100 \cdot \{|X_i - 2X_{i-1} + X_{i-2}|\}\end{aligned}$$

where N is the number of observations in the original time series, $\max L - \min L$ – the difference between the maximum and the minimum value of the observations of the original series.

If the theta index is greater than 0.007, we can speak about the strong role of the random component in the sequence. Then a new smoothed sequence is calculated, each k th term of which is the arithmetic mean between the $(k - 1)$ and $(k + 1)$ level of the previous sequence. This sequence will already be somewhat smoothed relative to the previous one. As far, it allows you to determine the value of the theta index for already calculated sequence. Since we are interested in the maximum deprivation of a given sequence of the cyclic component, the calculation was carried out until the difference between the theta indexes of the obtained and the previous sequence would be less than 0.01.

4 Results: programme description

The program was developed by means of VBA for Microsoft Excel. When opening an application file, the user enters the standard Microsoft Excel file, where the original database has already been imported. However, users can download their data to run. When you make changes to the database, the user sees an application menu that appears automatically. There the analyst can either go directly to the analysis and get acquainted with the information about the program and its authors.

The application interface has been specifically designed to be concise so that the user can intuitively work with the program without confusion in different windows, tabs, and the like. The user can at any time start analyzing the time series, which is to derive the most smoothed sequence, which is a trend estimate, the value of the cyclic component, and a graph that reflects cyclic fluctuations relative to the trend. The program works for any size of the database, which is a significant advantage of it, and the process of work itself is fast, start-up-intuitive.

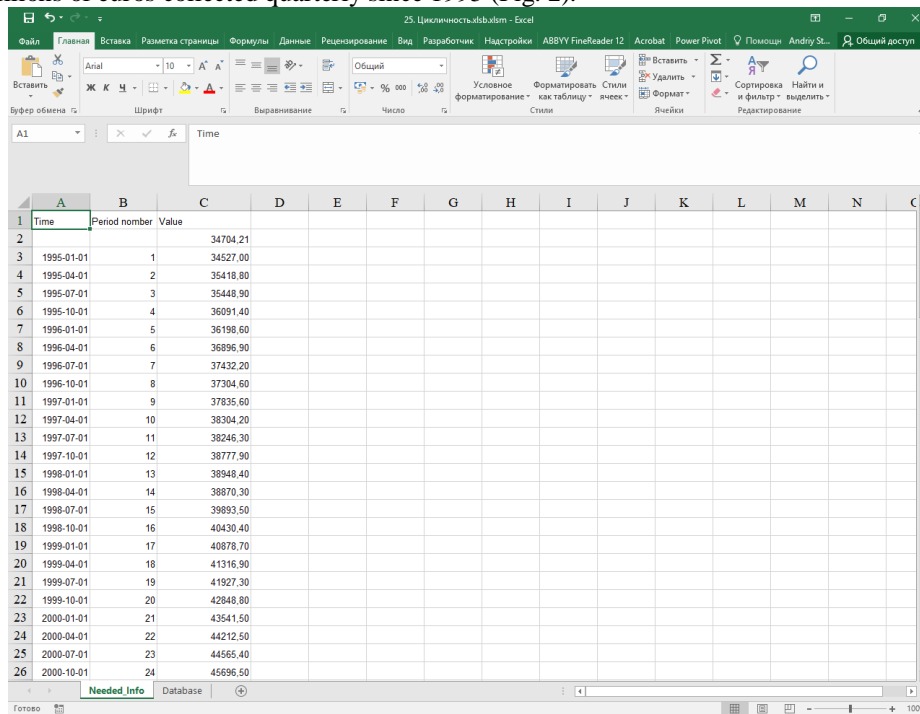
The system is not overloaded with the choice of different parameters, because the user only loads the required database, all parameters are calculated using the method Assimokoupolos within the code, so the user is completely burdened with the need for mathematical calculations. If the user is not familiar with the concept of theta index, it will be enough to see a graph that shows the cyclical fluctuations of the initial sequence relative to the trend, or he can read the instructions to the program.

Thus, one of the biggest advantages of this information system is its extraordinary ease of use. The user can make changes to the database if necessary to analyze another time series. The pressing "Go to Analysis" button is affordable even for a person

who is unfamiliar with time series analysis, that makes the proposed IT decision users-friendly one.

5 Case example

As the case example, we propose a time series of the value of Denmark's GDP in millions of euros collected quarterly since 1995 (Fig. 2).



Time	Period number	Value
		34704,21
1995-01-01	1	34527,00
1995-04-01	2	35418,80
1995-07-01	3	35448,90
1995-10-01	4	36091,40
1996-01-01	5	36198,60
1996-04-01	6	36896,90
1996-07-01	7	37432,20
1996-10-01	8	37304,60
1997-01-01	9	37835,60
1997-04-01	10	38304,20
1997-07-01	11	38246,30
1997-10-01	12	38777,90
1998-01-01	13	38948,40
1998-04-01	14	38870,30
1998-07-01	15	39893,50
1998-10-01	16	40430,40
1999-01-01	17	40878,70
1999-04-01	18	41316,90
1999-07-01	19	41927,30
1999-10-01	20	42848,80
2000-01-01	21	43541,50
2000-04-01	22	44212,50
2000-07-01	23	44565,40
2000-10-01	24	45696,50

Fig.2. Data source. Source: Eurostat.

Running the program allows a user to make the necessary calculations (Fig. 3). The columns of the MS Excel sheet contain the name of each period, its ordinal number, the actual value of the time series, as well as two calculation columns: trend estimation and cyclic component estimation. Accordingly, if we subtract the value of the cyclic component from the real value, we can analyze the new time series without the influence of cyclicality. It is also possible to analyze separately the value of the column of the cyclic component, which allows us to find an economic justification for certain changes in the time series behavior.

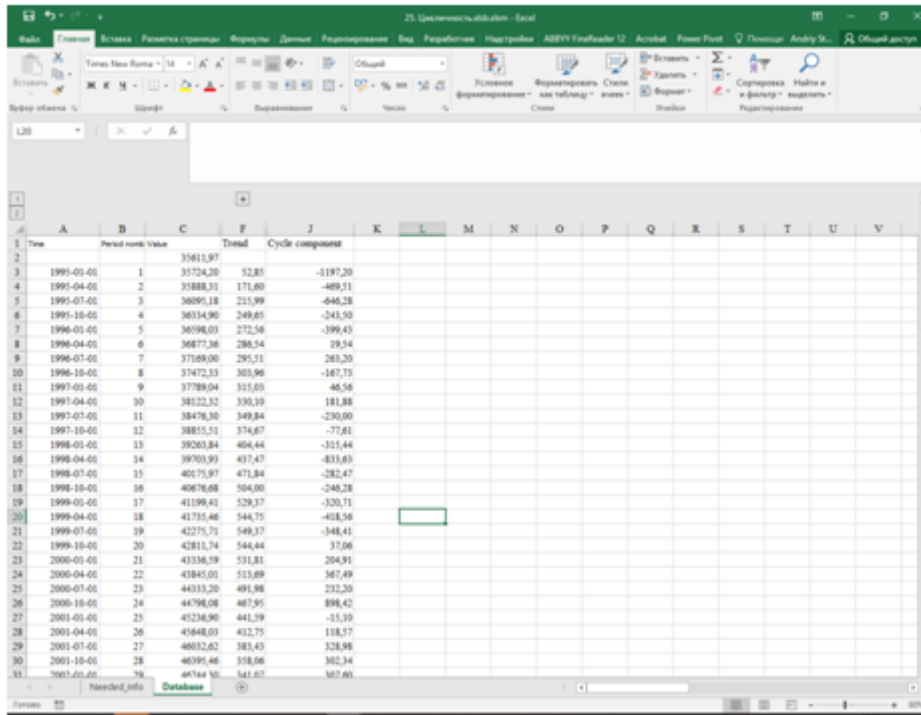


Fig.3. Information system calculations for obtaining the cyclic component of time series. Source: authors'.

Finally, one can construct a graph comparing the real value of the studied variable and the obtained forecast of the selected trend component (Fig. 4).

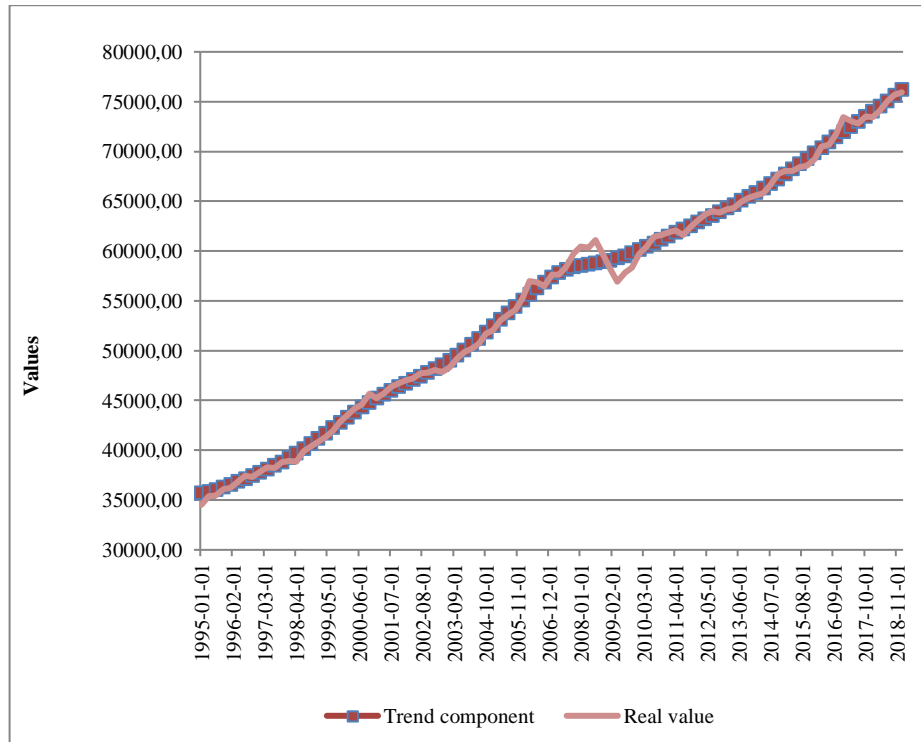


Fig.4.Trend component vs real data. Source: the calculations of the information system.

In the last step, one can build the dynamics of the cyclic component of the time series (Fig. 5). This graph is based on the calculated column of the cyclic component in Fig. 3.

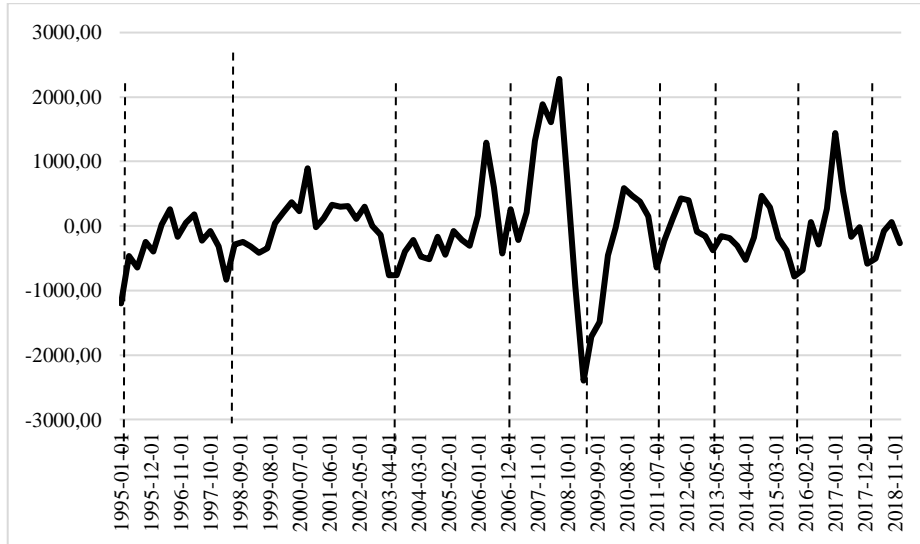


Fig.5. Cyclic component dynamics. Source: the calculations of the information system.

The graph allows determining the phase of economic growth from the beginning of observations until August 2008, when the global financial crisis began. But this growth was not homogeneous from 1996 to 2008. There were three small cycles: from January 1996 to April 1998, from May 1998 to April 2003, from May 2003 to December 2006. Finally, since 2007, the fourth cycle has come and ended with the financial crisis, that is, the end of a stronger long cycle. At the same time, the cyclical situation since 2009 has not been so clearly observed, because the governments of European countries, particularly Denmark, have pursued a stimulating fiscal and monetary policy, which has approved to be acyclic. But even under these conditions, the presented information system can identify three small uniform cycles of about 2 years in length, as well as the fourth wave with significant growth. If there had been no active state acyclic policy, a serious crisis would have been expected at the end of 2017 related to the end of the longer cycle. However, appropriate stimulus measures delayed the crisis. As it turned out for another short two-year cycle: the economic recession has been starting in the first quarter of 2020. Fig. 5 demonstrates the corresponding limits for the phases of the cycles, which can be determined from the data of the developed information system. It should be noted that this provides only a basis for the researcher for further analysis, as it is necessary to compare the obtained phase breakdown with the real economic or other factors that influenced the time series data. However, such an analysis must be individual in each case. For this paper example, it can be concluded that the lessons and consequences learned from the 2008 global financial crisis changed the size of short cycles (from about 3 to 2 years) but did not change the length of the longer cycle. Therefore, there were not 4 but 5 shorter cycles between crises.

As one can conclude, a series of cyclical fluctuations obtained employing the information system allows making a quite valuable conclusions, but also to predict

the onset of economic, financial and other shocks. The better identification of cycles allows better policy reactions and enhances the attempts to predict naturally occurring cycles that is especially problematic if they are no longer naturally occurring.

6 Conclusions

The issue of allocation of the cyclic component is an important element of successful forecasting in all areas of activity. Correct allocation of the cyclic component in time series may be of interest to:

- governments and central banks to adopt changes to fiscal and monetary policies to avoid market distortions as a result of overproduction in certain sectors;
- managers at firms to formulate more adequate sales and procurement plans for the warehouse, create timely advertising campaigns to increase profits;
- ecologists to analyze climate change on the planet;
- doctors to analyze the recurrence of epidemic diseases;
- scientists to study a new class of time series voiding the cyclic component.

Obviously, further research should address how exactly economic and other cycles converge across countries, regions, industries. It will be able to provide information to shape relevant economic, environmental, health and social policies in the world.

The authors have created an information system that displays the smoothed sequence with the entered time series, which is a long-term trend, as well as the values of cyclic fluctuations with the further graphical display of the result. The program works simply and effectively, with repeated testing no problems were detected. This information system enables users to easily select cyclic fluctuations from an arbitrary time series. Obtaining this data allows researchers more often referring to the analysis of the cyclic component, motivating the study of dynamics and determining the factors that influence it.

With the help of the developed IT system, an example of a complex pre-forecast analysis of output time series in the field of economy is shown. The results of the application revealed the performance of the IT system and provided new knowledge about the objects of analysis and forecasting.

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Item Matching Based on Collection and Processing Customer Perception of Images

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Abstract. The number of sellers and goods being sold on the e-marketplaces is growing, so the volume of data stored and processed by e-commerce information systems is increasing drastically. That is why the development of performance solutions is quite relevant. The given paper provides the approach of item matching based on the human perception of item images. The main goal of the study is to build a model for assessing the similarity of items. This paper provides a description of a software product for comparing product images collected on online trading platforms. The user evaluates the product visually. The developed software implements the crowdsourcing data collecting based on the comparator identification method. The use of this method involves an experiment in which the user is offered two images, by comparing which the determined binary reaction is obtained. The results show the perspective of the mobile client application as part of an item matching system that aims to optimize the search for products on the Internet.

Keywords: Product Matching, Crowdsourcing, Mobile Application, Customer Perception, Comparator Identification

1 Introduction

Digital transformation in all over our life is expeditiously growing nowadays. The amount of sellers and buyers via the Internet has increased for the latest years drastically. The current situation caused by Covid-19 makes new challenges for the community. Ukrainians like a lot of people in the world need to live in the circumstances of quarantine. It forces individuals to use online applications more often for purchasing goods. For some categories it is the first trial, for others, it can be commonplace. But in both cases, a problem of the huge amount of commodity propositions rises. In order to simplify the process of choosing the product for the buyer the amount of offered goods should be reduced by grouping them on similar features. In order to solve such a problem, online trading platforms provide different tools like filtering, recommendation, and so on. The issue of item matching has been already treated in our previous papers [1, 2]. In our experiments, we collected descriptions of commodities from different

trading platforms and grouped them according to similar characteristics. Those experiments showed good results partly because of the type of product. We made experiments with mobile phones and bicycles. Such commodities have a lot of clear quantitative characteristics. Concerning items that are described not so good set of attributes the images could be taken into consideration. The human perceives visual information naturally and makes decisions based on there. In this paper, we suggest using the human ability to perceive and divide visual images to collect data about item similarity.

There are a lot of researchers try to solve the item matching problem. In the paper [3] for product matching, the similarity function was proposed to compare products based on their attributes. Before applying this approach, each attribute has been categorized into a class that defines a specific similarity function that processes this attribute [3]. The process of classification is built on regular expressions. Also, a match function relied on the semantics is used for matching unstructured product offers [4]. A match function considers matches along with mismatches in attribute values between proposed commodities and distinguishes whether the attribute value is missed or mismatched. The study [5] provides an analysis of existing frameworks for entity matching and concludes all frameworks concentrate on offline matching. Analyzing existing approaches it is found out, that all of them have drawbacks and don't provide the general scheme to solve the studied task.

The image processing is also engaged for item matching [6]. Natural language text generation from commodity images is one of the issues examined by the research community. Corpus from the online market was processed by the generation model and described by humans [6]. The results of the experiment showed, that the generation model learns effectively from noisy online data. But there is a big difference in results if the type of task is the attribute-centric language generation and generic product description.

This paper represents the empirical study towards the creation of the tagged collection of item images creation in order to investigate their similarity and perception by the end-users of the e-market.

2 Our approach

The usage of the Internet and social media helps researches to collaborate and create value together. We suggest using a crowdsourcing approach in order to collect estimations of item matches. The term crowdsourcing was first used by Jeff Huff in 2006 in Wired magazine [7]. Crowdsourcing means engaging the general public, through the Internet, in research and solving public problems. Crowdsourcing presumes a process of combining individuals, paid or unpaid who are joined together with a shared interest and are able to increase results thanks to their aggregated actions. This approach can offer researchers access to new opportunities for co-creation, task optimization, and costs reduction. Concerning the study of items matching the crowdsourcing approach is the only way to obtain the data required. Due to creating the similarity model of items proposed on web sites and trading platforms the huge amount of tagged data is needed.

Analyzing a lot of up-today evaluation approaches we found out the pairwise comparison is the best way for human. Following the Theory of intelligence [8], we propose to take into consideration the feature of human intelligence and their ability to perceive images. So, according to [8], the person is called examinee in case his intelligence is being studied. In the process of examining the behaviour of human intelligence, it is important to research internal subjective state and information processing, which cause a particular way of behaviour. In order to research examinee internal state, the method of comparator identification is used [8]. The method of comparator identification is a type of indirect identification which is a mathematical description of some processes from real life. The examples of internal state are images and representations of real goods. We present the image of the product and get the perception as an assessment of the internal state.

Comparator identifies whether its input signals are in proper relation. And then the comparator reacts with a binary signal equals 1 if the relation is confirmed. The example of comparator work in human consciousness is comparing the images of goods. The method of zero instrument is a widely used approach for research the internal state of the intelligence system [8]. The key idea of the method is quite simple. Let us consider x_1 and x_2 are two images, which comparator perceives as objects y_1 and y_2 . If the objects are the same, then examinee should answer "yes". It means that the perception of images of similar products is the same.

According to [8] the internal relations can be represented with a special function like predicate. The predicate of equivalence is every two-place predicate, which is reflexive, symmetrical, and transitive. By analogy with the predicate of equivalence, we propose to consider the predicate of item similarity. The reflexiveness of the predicate of item similarity means that the same items correspond to the same image. The symmetry of the predicate of item similarity means that in the case of shifting the place of images the equality of items is the same. The transitivity of the predicate of item similarity means that if the first and the second items are the same and the second and the third items are the same, then the first and the third items are also the same.

Thus, just observing the examinee we can obtain data about item similarity based on pairwise comparison of item images. That is why we need a tool to implement the method of zero instrument. Therefore, in the given work we suggest developing a special tool like a mobile application for observing the examinee and implementing a crowdsourcing approach for collecting data.

3 Image Matcher Application Design

The developed software component is an Android-mobile client, which provides end-user with the mechanism of comparing the products represented in the images. The user has the ability to compare images in pairs and indicate the similarity or difference of products offered for comparison. Before starting to compare the goods, the user should pass a questionnaire where they indicate gender and age. Proposed questionnaires are anonymous; their data are used only for the determination of correlation between the results of user data and the result of the comparison. The data provided by end-user is

collected in cloud storage and further will be used for structuring and analysis to provide an efficient search of goods through Internet trading platforms.

The main goal of the study is to build a model for assessing the similarity of items. To achieve this goal developed system should contain the client-side and server-side, where the questionnaire result would be stored. In the proposed solution, the Android application serves as a client-side, and the Firebase Cloud platform serves as a database and files storage. The examinee interacts with a user interface, passes an anonymous questionnaire and sends data about the comparison of item images. The component diagram of the proposed software presented in fig. 1.

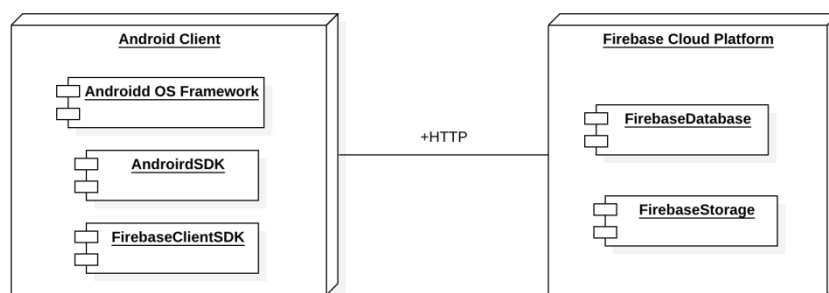


Fig. 1. Component diagram of developed software

The software emits new image files from remote file storage (Firebase Storage) each time it asks whether represented items are similar or not. The result of the comparison provided by the examinee is sent directly to Firebase Cloud node via HTTP-protocol where it would be validated and stored. Each user session has its unique ID to make data analysis more efficient by grouping data provided in the questionnaire.

The described user flow depicted in fig. 2. Each flow of the developed system is presented as independent components. Each component has its own package with a set of classes to provide the required functionality. Accordingly to MVP (Model–View–Presenter) pattern each package contains view interface, presenter class and dependencies which are necessary to implement set objectives. The system constructed as a serverless application without implementing any logic for sending, validation and storing data to storage. Instead of this, the decision was made to use a PaaS approach and integrate the Firebase platform which provided such functionalities.

The benefits of the serverless approach follow. Reduced time to market and quicker software release are present. Lower operational and development costs is needed. A smaller cost to scale – there is no need for developers to implement code to scale and administrators do not need to upgrade existing servers or add additional ones. Works with agile development allows developers to focus on code and to deliver faster. Serverless approach fits with microservices, which can be implemented as functions. It reduces the complexity of software. It simplifies packaging and deployment and requires no system administration.

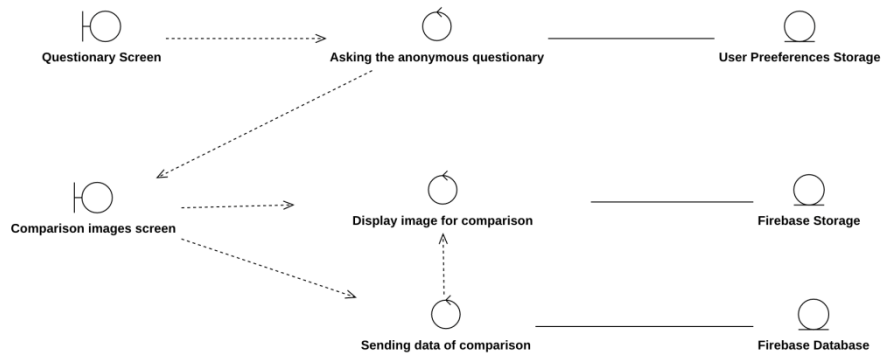


Fig. 2. User flow diagram

At the same time, “serverless” has the following drawbacks. Serverless is not efficient for long-running applications. In certain cases, using long tasks can be much more expensive than, for example, running a workload on a dedicated server or virtual machine. Also, you are depended on platform availability, and the platform’s API and costs can change. Serverless (and microservice) architectures introduce additional overhead for a function or microservice calls. There are no “local” operations; you cannot assume that two communicating functions are located on the same server. To utilize its resources more efficiently, a service provider may run the software for several different customers on the same physical server (this is also known as “multitenancy”).

Let us give a short data description. Before the user starts the comparison image of the product they should pass the questionnaire where they provide information about gender and age. To make it more efficient these fields were composed in two fields named “info”. This field is bit-mask of three bits where first bit represented user gender (“0” – Male, “1” – Female) and two bits of user age (“01” – younger 20 years, “10” – between 20 and 40 years, “11” – older 40 years). The division of respondents on such age groups is caused by the difference in their perception of information. People till 20 years mostly behave like pupils and carefully compare pictures, they try to find totally the same goods. Respondents aged 20 to 40 are often intelligent, have a job, use the internet actively. They are less careful and count similar things as the same. People aged after 40 use the internet less. They can have perception different than the active younger generation. So, the result of the questionnaire would be an integer value that contains information provided by the user. Because of using a NoSQL database, the result of the comparison is stored as a tree of nodes, where the parent node is user-session information and result of comparison represented as child-nodes. The example of stored data presented in fig. 3. The stored data can be exported as JSON file and analyzed using tools that can read and parse data in such extension.

Because of serverless architecture, it is required to create a thick mobile client that communicates with the Firebase platform using the appropriate protocol. The android application contains package modularization according to the CLEAN-architecture approach. It consists of such classes as CoroutinesUtils; Storage; MatchingModel; Domain; UserUtils and etc.

User interface is constructed accordingly to Material Design Approach. When the user starts the app they could see an introduction screen where describes the scope and aim of the current evaluation. This screen serves as a guide through the application. After reading this guide users navigate to the questionnaire. After passing the questionnaire user navigate to image comparing flow where depicted two images of items and the user determine similarity. If goods represented by the image are the same according to the user's perception they could press the button with text "Yes" and "No" otherwise.

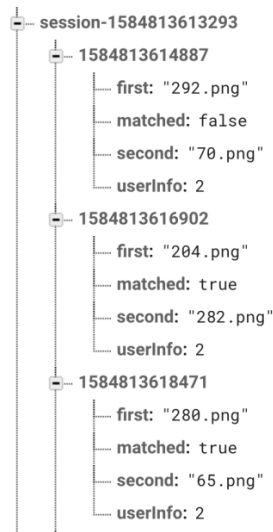


Fig. 3. Example of dataset stored in database

If the user wants to finish the comparing he could press the "Finish" button and the application would be closed. After reopening application flow of interaction begins from the guide screen. The questionnaire screen and the image comparison screen are given in fig. 4.

Therefore, the application has a user-friendly and intuitive interface. The user actions and navigation is clear and might not produce misconceptions while using the application.

4 Case Study

The case study of the given work is based on images collected from eBay trading platform (<https://www.ebay.com/>). The web crawler component launched on the website has gathered web pages that contain jackets being sold. Then we separate images and text descriptions. In the given study we use only images. The number of images used in the experiment is 311. All images are collected in the same format. In the given experiment we use *.png format.

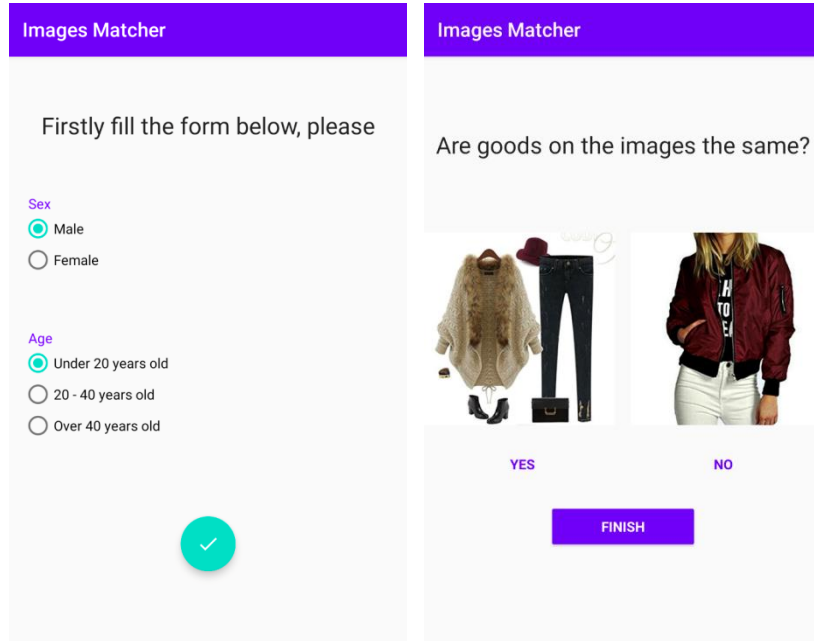


Fig. 4. Questionnaire screen and Image comparison screen

The overall description of the image data set is presented in Table 1.

Table 1. Image data representation.

Text Genre	Number of items	Number of similar items
<i>Men jackets</i>	174	37
<i>Women jackets</i>	137	29
Total	311	66

In order to test our approach and the mobile application, we ask 9 people to make the comparison based on the given data set. The figure 5 shows the distribution of the number of images that compared different categories of users as well as number of similar items they recognized.

The main purpose of the future work with the Image Matcher application is an analysis of item similarity based on its images. Caused by our plans we take values of an average number of items evaluated by each type of user and an average number of items recognized by each type of user (fig. 5) and try to analyze these values. Figure 5 shows that the “female, between 20 and 40 years” category has the highest number of evaluated items on average but “male, younger 20 years” has the most number of similar items. It can help us to future research for item matching estimation.

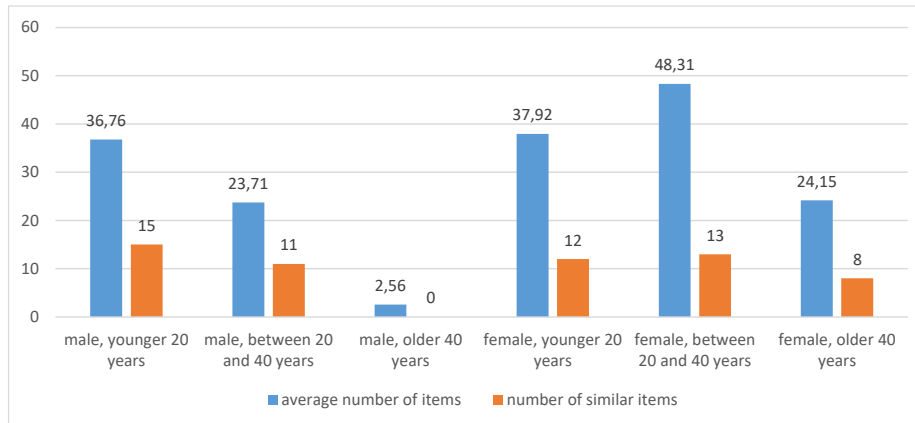


Fig. 5. Data distribution according user type

In this paper for our first time hosting we presented the results of conducted a trial run. It is too early to make any conclusions about the similarity of goods, which photos have been compared. We just proved that a proposed approach is suitable for solving such type of issue. In order to decide how many buyers should take part in the questionnaire and how to gather a representative sample, the marketing specialists should contribute. In future work, it is supposed to solve the problem of gathering and tagging a data set. After that, a link for access to this app could be distributed.

5 Discussion and Conclusion

A huge amount of electronic marketplaces are used for commercial exchange. In order to represent their products sellers usually give commodity image and textual description. Buyers in their turn look at the picture and read short descriptions. Moreover, because there is an enormous quantity of goods it is exhausting for a purchaser to look through all propositions. Using recommendation systems e-commerce platforms attempt to solve this problem. They try to single out product attributes and ask sellers to fill in. However, here arises the problem of item description normalization.

Onlooking for human behavior states that people more often firstly pay attention to pictures and then look through textual descriptions. Thus, we have worked on a data set, which could be tagged according to customer estimations. We suggest using crowdsourcing for tagging item images. The mobile application is developed for multiplying sampling. The simplicity of mobile application allows using it by a diverse people population. The application can be used just for fun and bring social benefits. An increasing amount of tagged pictures permits to investigate customer perception, which also depends on age and sex.

We intend to show the way of gathering data for estimating product offerings. As far as customers have no opportunity to touch products, the perception of a commodity depends only on image and text description. Clustering product offers into similar

groups can significantly reduce the search space and alleviate the process of choosing a commodity.

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Deliverology Implementation at the Local Government Level of Ukraine

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Abstract. The article is devoted to the application of deliverology at the local government level in countries comparable to the stage of fiscal decentralization implementation as in Ukraine. The aim of the article is to show how the application of informational technology can contribute to the implementation of deliverology at the local government level as in the example of Ukraine. The methodology is based on the application of Difference in Difference method and the development of basic program codes for the implementation of deliverology at the local government level. It is proposed that multi-criteria methods of decision making be used to analyze information which is most often formalized in the format of groups of performance indicators of local budget programs. Further research may be necessary to develop recommendations for the use of a single standard of electronic databases for regional development indicators and local budgets. This will allow the full automation of the process of managing data on local government performance.

Keywords: Deliverology, Multi-criteria methods, Difference in Difference, Program code.

1 Introduction

Deliverology ideas were first introduced by former UK Prime Minister Tony Blair's office to ensure that election promises were kept. The main components of deliverology are setting goals that are based on previously stated priorities, evaluating target indicators, and using tough feedback channels to monitor the achievement of goals. This approach has proven effective in public administration not only at the national level, but also at the sub-national level [1, 2]. Small group of professionals monitors the ways to improve the quality of public services focused exclusively on achieving impact and improving outcomes. To project a high-level public management vision into reality they build optimal models for the services provision based on widely collected data, sets goals for their implementation, and disseminate the good practices [3]. The approach is centralized and requires external transparency for public service data.

Deliverology is, in fact, a citizen-centered approach. In addition, it is a performance-based approach that requires transparency and accountability. The implementation of this approach requires the organization of work with large amounts of information, which cannot be organized without the use of information technology (IT). Information technologies are those that allow a reduction in the cost of database development, updating, analysis and monitoring of data for stakeholders, and so on.

This approach is partly used in post-communist countries, although the need for it is much higher there due to higher risks of corruption, including political corruption. It should be noted that there is no single approach to the development of deliverology, as the process of deliverology implementation is influenced by the institutional environment, the legal and regulatory framework, and the economic condition of the country.

The prerequisites for local development in Ukraine emerged after the consolidation of mid-term budget planning and amendments to the Budget Code in 2019 [4]. The amendments to the Budget Law consolidated typical forms of local budgets and organized the consolidation of tasks of local authorities. Deliverology ensures that planning for budget expenditures is not only decentralized but also focused on achieving national strategic objectives. It should be noted that implementation of deliverology at the local level in Ukraine is slow as there are no appropriate software tools to deal with heterogeneous information on the implementation of budget programs.

The aim of the article is to show how the application of information technology can contribute to the introduction of deliverology at the local level using the example of Ukraine.

The article is organized as follows: the literary review of the investigated problem is conducted in the second section. The third section describes the research methodology. The fourth section displays the main results of the study. The fifth section presents findings and prospects for further research.

2 Theoretical Background

According to Watkins (2013) deliverology is defined by many researchers as a control system that ensures maximum success [5]. Success is achieved through an approach that closely links expected results to current activities [5-7]. At the same time, current results are continuously monitored to adjust the actions of the implementers. It should be noted that this approach requires working with large volumes of data, their continuous processing and analysis. Rapid response to changes in performance indicators allows timely adjustment of tactics to achieve the set objectives.

Deliverology is seen by many researchers as an approach to improving public administration [8-9]. Gash, T., Hallsworth, M., Ismail, S., and Paun, A. believe that improving the quality of public administration is achieved through clear goal-setting and rigorous monitoring [10]. The achievement of objectives is often linked to the provision of adequate quality public services. Therefore, timely information on the current state of affairs is needed to achieve the stated outcomes.

Bouchal, P., Kidson, M., Norris, E., and Rutter, J. argue that the implementation of deliverology contributes to social justice [11]. This effect is achieved by increasing

government accountability, both at the central and local levels. Publishing timely information on the funds received and the results of their use helps reduce the risks of the inefficient use of taxpayers' funds.

Some researchers compare deliverology in the public sector with performance-based management in the business sector. They believe that it is the focus on results that contributes to the effectiveness of government [12, 13]. Many scholars have also studied the impact of deliverology on improving the quality of education, health care [14], and government cost effectiveness [15]. The most recent publications, for example Birch, L., Jacob, S., & Baby-Bouchard, A., Haws, E., Jakobsen, M. L., Baekgaard, M., Moynihan, D.P., & van Loon, N., discuss the role of deliverology in delivering on election promises and increasing government accountability [16-18]. In other words, the role of deliverology is increasing, and in the future the need to implement this approach in the public sector will increase.

Implementation of deliverology ideas in practice requires working with large amounts of information, so the use of the deliverology approach in practice requires the application of information technology. Information technology has been most successful in introducing deliverology into education and medicine [19]. Ideas on the use of computer technology for evaluation of results are presented in Barua A, Kriebel C, Mukhopadhyay T [20]. Critical evaluation of the information technology approaches used to measure results is found in Dedrick J, Gurbaxani V, Kraemer KL (2003) and Jarvis, C. B.; MacKenzie, S. B.; and Podsakoff, P. M [21, 22]. The main idea of the application of information technology in the implementation of deliverology is to create simple and quickly adaptable software products that allow the quick collection of information, processing of it, and publishing of the results in the required format.

3 Methodology

The research methodology is based on qualitative and quantitative methods. Qualitative methods were used to describe the implementation of deliverology principles in the work of local authorities, as well as to determine performance indicators of budget programs. As a main qualitative approach case study methodology was used. The main purpose of the case study is to provide an in-depth analysis of the problem in terms of understanding the qualitative characteristics of the object of a study [23]. In our research the object is the local government level of Ukraine. The data for the research were selected based on an analysis of local government press releases on key approaches to improving public service delivery.

The performance indicators in the selected budget programs are designed for public services, delegated by the central to the local level within the framework of public functions, such as provision of public goods in the sphere of education, health care and social protection. Since Ukraine consumes a lot of energy resources, energy savings indicators are envisaged as targets in the budget programs of local authorities for recent years.

Quantitative methods are used to develop an algorithm for collecting data on indicators, as well as to calculate performance indicators. This algorithm has been developed

for implementation in local government practices. For this purpose, the software environment R was used. With the help of R, two goals were achieved:

1. An algorithm for collecting statistical data for calculations has been developed.
2. An algorithm for calculating performance indicators using the difference in difference method has been developed.

The data is available on the websites of local authorities. The technic of “data scraping” was used in this research. The difficulty of collecting statistical data is that most reports on the implementation of budget programs are presented in PDF format. Such libraries were used to transform this data into a table form and form a database:

```
library(rJava) Needed for tabulizer
library(tabulizer) Tool for PDF Scraping
library(tidyverse) Core data manipulation and visualization
libraries
```

A fragment of the program code to obtain a table on the performance of budget programs is presented below:

```
# PDF Scrape Tables
Budget_indicators_scrape <- extract_tables( file = "program_oblast.pdf", method = "decide", output = "data.frame")
```

The package DID was used to calculate the indicators by the Difference in Difference (DID) method. DID is usually implemented as an interaction term between time and treatment group dummy variables in a regression model (1) [24].

$$Y = \beta_0 + \beta_1 \times [Time] + \beta_2 \times [Intervention] + \beta_3 \times [Time \times Intervention] + \beta_4 [Covariates] + \varepsilon \quad (1)$$

DID is typically used to estimate the effect of a specific intervention or treatment (such as a passage of law, enactment of policy, or large-scale program implementation) by comparing the changes in outcomes over time between a population that is enrolled in a program (the intervention group) and a population that is not (the control group) [24]. In this research the intervention group is the group of regions which have implemented deliverology approach. As dependent variables the indicators of energy efficiency and energy effectiveness were used. The covariates are normative indicators for the country. The calculations were done for two periods: 2016-2017, 2017-2018.

The DID package contains tools for computing average treatment effect parameters in Difference in Differences models with more than two periods, with variation in treatment timing across individuals, and where the DID assumption possibly holds conditional on covariates.

4 Results

4.1 Deliverology Organization at the Local Government Level

A key aspect of local government effectiveness is to provide public services of appropriate quality to taxpayers. One of the important factors in ensuring local government performance is to raise awareness among all actors in the supply chain of such services about their results and costs.

The founder of the deliverology Barber et al (2011) identified three key components of the approach:

1. Centralizing decisions in the hands of a small group highly skilled professionals who provide a systematic approach.
2. Accumulation of reliable and relevant performance data to determine goals and trajectories for achieving them.
3. Establishing daily implementation of the chosen concept [25].

To implement deliverology at the local government level, standard budget programs should be established first. Further development of a constantly updated information system which will accumulate the information on planned and actual indicators of performance of budgetary programs is necessary. This information system should be uniform for all local governments so that information on the implementation of budget programs is collected, processed and published according to a single standard. The system should make possible the accumulation of data over several years and analysis of their dynamics.

The initial information should be presented in fields such as the following:

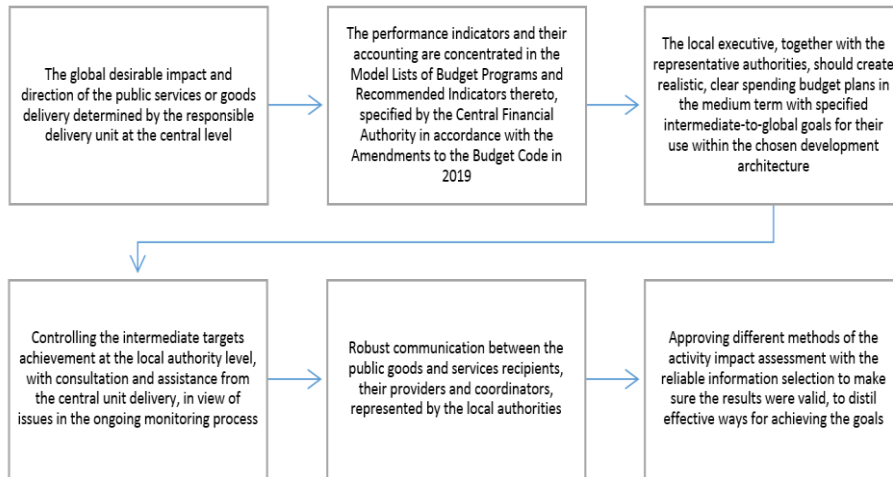
1. By groups of indicators of implementation of local budgets (expenses in absolute value, product/service, indicators of efficiency and effectiveness).
2. By functions of budget programs.

Currently in Ukraine the first step in the creation of a complex information system has been made, namely, the data portal of the "Open Budget" system. Information on local budgets is now stored in a data repository, where it should be timely updated as new data becomes available. The original information is displayed on a special website (link openbudget.gov.ua), but efforts should be made to separate results in a graphical form and sample data analysis be available upon request of a particular user.

Coordination of information exchange in deliverology can be achieved by providing information to different user groups. For example, Corrado lo Storto (2014) suggests using a "cognitive user system" [26]. The idea is that public officials need information that immediately generates ways to implement country and local government policies. First, it means compliance with targets, implementation of strategic criteria, selection of indicators by form in dynamics with grouping by administrative units or budgets, etc. For analysts and researchers, information can be provided from primary sources grouped according to common criteria: period, type of budget, cost objectives, planned and actual indicators. For ordinary citizens the information should be summarized in graphical form with necessary details and maximum transparency. With the availability of such a service, citizens can easily see the quality of public services in their region and beyond. According to Barber and others. (2011), the evaluation of the beneficiaries

of public services and goods is an integral and important part before the end of the service cycle [9].

Based on users' information needs, deliverology at the local level should be organized as shown in Figure 1.



Source: Developed by authors based on [8, 9, 25]

Fig 1. Deliverology stages at the local level

Possible difficulties for establishing credible performance indicators for the public goods and services provision in Ukraine are:

1. Qualitative indicators of budget programs measure the result of the activity of the performer, but not the ultimate objective achievement.
2. According to the volumes of information, in the accumulation of results it is reasonable to consider a future system by big data characteristics in the public sector [27, 28].

The general scheme of the Big Data system construction at the local government level is shown in Fig. 2.

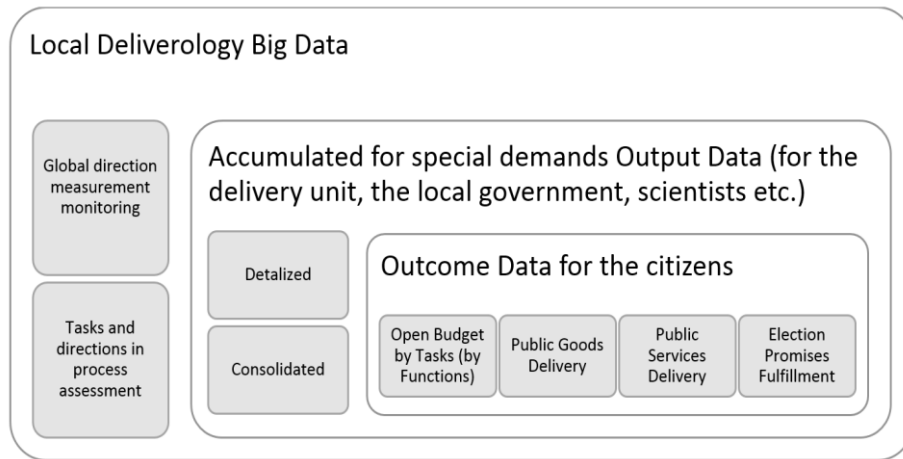


Fig. 2. Local deliverology Big Data system

Big Data system for local deliverology should be implemented in at least two aspects.

1. The first part is a framework with indicators for the general monitoring of policy implementation, development indicators, and forecast trends for available resources in the region. The system's use of these indicators is aimed at maximum objectivity and automation to determine deviations. This part includes, for example, such indicators as employment, average official income, number of employees in the public sector with the projected amount of taxes paid by them and other similar indicators. This part should also include indicators of the real estate tax base, the amount and cost of energy consumed, the level of infrastructure development, its depreciation, cost and profitability, and other indicators. The problem of Ukrainian governance, in particular, is to assign the role of a forecasting tool that simulates a desired result that is far from reality. This leads to the fact that plans based on such forecasts cannot be implemented in practice. After implementation of deliverology, the dynamics of key indicators built into forecasts and displayed in the system of indicators would publicly outline the framework of forecast realism using IT tools. Thus, the central government and local authorities will strengthen the consensus in the provision of services, stipulated in the budget legislation from 2020. Taxpayers will be able to understand the real business environment.

2. The second part consists of consolidated information in the form of standard dashboards and detailed individual data sets for analytics by type of services. This part has the primary task not to standardize but report the completeness and consistency of collected data on services. Further requests from the population and authorities, performed by IT specialists, will form the environment for the most convenient use of information about the activities of the authorities in the regions.

4.2 Simulation of Results

As noted above, the development of an information system for the implementation of deliverology approaches requires software that allows timely collection of data, their processing and publication in the required format. To simulate this process, software codes have been developed to collect and analyze data related to energy efficiency assessment. Energy efficiency was chosen as a pilot indicator because one of the strategic objectives at the national level is to reduce energy consumption. That is why energy efficiency indicators are subject to special monitoring in all budget programs.

Some performance indicators from typical passports of the local budget program, which relate to the task of energy saving by the executing agency, are presented in Table 1.

These indicators are used to assess outcomes for individual budget entities. They allow a comparison of the results of local government energy efficiency policies with and without declared energy saving measures by regions.

Most of the reports on budget execution are published in PDF format. To collect the indicators, a software code in R has been developed that automatically reads data from the reports and creates worktables. A fragment of the program code is shown in the Methodology section.

Table 1. Performance indicators of the local budget programs for the energy saving task

The effectiveness - utility consumption level	The norm indicator (for the whole country or in a particular region)	Indicator accomplished in the budget program for the period 1	Indicator accomplished in the budget program for the period 2
Heat supply (H), Gcal per 1 m ³ of heated space	N _h	H ₁	H ₂
Electricity (E), kWh / m ²	N _e	E ₁	E ₂
Water supply (W), cubic meters per square meter	N _g	W ₁	W ₂
Efficiency (Quality) – the level of savings	Cost savings for a specific region or the country	Accomplished in the budget program for the period 1	Accomplished in the budget program for the period 2
The level of heat supply saving (H), %	NE	EH ₁	EH ₂
The level of electricity saving (E), %	NE	EE ₁	EE ₂
The level of water supply saving (G), %	NE	EW ₁	EW ₂

The "Difference in Difference" method described in Wooldridge's (2009) was used to estimate the difference in energy saving indicators across regions [24]. The DID method allows the budget program implementer to compare homogeneous metrics in

the service group over a number of years and measure the results of the energy efficiency policy. The difference comparison method shows how the energy consumption of each individual producer changes over time in different regions. It differentiates regions with different approaches over time to account for their impact on typical changes in indicators. Differences in groups of indicators of typical tasks of budget programs under this method aggravate exceptions in indicators of efficiency of consumption or saving of consumed public utilities between regions. Estimates of consumption by regions may indicate the presence or absence of changes in the dynamics of energy efficiency. Interpretation of the results will depend on the goals and conditions of the utility company. A country specific norm or efficiency indicator for any region, where an assessment of efficiency and quality of utility consumption has shown optimal results, can be considered as a benchmark for using this method.

Therefore, it is necessary to compare the changes in dynamics between the first and second periods in the activities of local public companies in Regions A and B with the optimal energy-saving results in Administrative Territory C, which in this case are adopted as "normative". For example, Regions A and B declare that they implement energy efficiency policies, while Region C uses energy in the usual way. It is necessary to determine whether Region C shows the best projected energy saving results or overestimates the efficiency targets in order to get the best cost savings in its budget programs?

The adapted sequence of formulas for the calculation is as follows:

$$\Delta u_A = (I_1 - I_2) - (N_1 - N_2).$$

$$\Delta u_B = (I_1 - I_2) - (N_1 - N_2).$$

$$P_{(AB)} = [\Delta u_A] - [\Delta u_B]$$

were 1 and 2 – periods when the performance indicators done,

A and B – finally comparable regions,

I – the performance indicator within a certain group,

N – the indicator of a comparable certain group from the standard (neutral) region

C.

Instead of manually calculating the four means and their difference-in-differences, it is possible to estimate the difference-in-differences estimator and its statistical properties by running a regression that includes indicator variables for treatment and after and their interaction term [29].

As stated in the Methodology section, for the automatization of calculations the package DID was used for R. A fragment of the program code is presented below:

```
library (did)
data (locdta)
summary (out$aggte, type="dynamic")
```

Also, the following options were used:

- "selective" - results when there is selective treatment timing
- "calendar" - results when there are calendar time effects

A sample of indicators on nine regions of Ukraine was created for analysis. Eight of them were compared with the ninth "normal" region in terms of consumption of selected utilities after the implementation of the budget programs for 2016-2018. For earlier periods, the reports are available only for the city of Kyiv. Therefore, calculations for earlier periods have not been performed.

The results of the calculations are presented in Table 2.

Table 2. DID method result in the energy saving calculation

Group number	DID in the effectiveness 2016-2017	DID in the efficiency 2016-2017	DID in the effectiveness 2017-2018	DID in the efficiency 2017-2018
1. Heat	0,6	5,5	0,3	5,6
2. Heat	2,2	2,5	2,6	2,5
3. Heat	0,9	7,0	1,4	7,2
4. Heat	1,0	3,9	1,1	3,8
1. Electricity	6,1	8,7	5,9	10,7
2. Electricity	3,4	7,5	2,2	7,6
3. Electricity	6,8	9,1	6,7	15,1
4. Electricity	8,8	11,6	9,7	14,5
1. Water	0,05	2,8	0,06	3,4
2. Water	0,07	5,2	0,13	8,2
3. Water	0,02	4,4	0,02	3,7
4. Water	0,08	2,9	0,09	3,8

The results of the analysis showed that electricity consumption is characterized by significant deviations. Therefore, electricity consumption by local authorities should be a priority in further evaluation.

The performance indicators that are assessed in local public services are consistent with the level of social orientation of the territory (average salary, emigration, etc.). Local governments need such an assessment in order to discuss a centralized approach to service delivery, with the implementation of the most reasonable and cost-effective solutions. Local government leaders should not, at present, simultaneously assess the various options for making such decisions on many variables, because their task is to centralize service delivery. However, some of the 'top-down' directions are conflicting (e.g., the impact of small school and kindergarten decisions on community well-being), sometimes factors that interfere with the final decision increase or disappear altogether. Therefore, the correctness and effectiveness of the decision depends heavily on the established utility metrics and assessment methods.

Multi-criteria decision-making methods, in our opinion, will ensure the best further assessment in these conditions. They allow the evaluation and analysis of multi-purpose tasks using combinations of different criteria.

5 Conclusions

The proposed information system for implementing the deliverology approach at the local level offers a number of advantages in the use of official information. First, the independence of local government is not compromised, but its patronage and accountability are ensured. Secondly, the collection and analysis of performance indicators over a period of time allows their quantitative and qualitative composition to be assessed and local government actions to be adjusted where necessary. Third, multi-criteria decision-making methods used to analyze performance indicators, combined with benchmarks, will create new opportunities for researchers in local governance.

The concept of development of deliverology at the local level proposed in this publication, based on the performance indicators of local budget programs in regions, is necessary to obtain unified data. In the long term, with the use of "Big Data" at the local level, data storage systems can be expanded through performance indicators of budgetary institutions, staff evaluation indicators, indicators of environmental and economic progress, etc.

One of the key obstacles to the introduction of deliverology at the local level is the lack of requirements for reporting information in a single format. Therefore, the sample for the calculations was limited to nine regions of Ukraine. Therefore, for further development of deliverology, it is necessary to develop a single format for publishing reports on the implementation of budget programmes.

The prospect of further research is to develop algorithms and program codes for the analysis of key performance indicators of budget programs and create on their basis a unified system of data storage and analysis for management decision-making at the local level.

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Developing Practical Recommendations for Increasing the Level of Digital Business Transformation Index

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Abstract. *Research goals and objectives:* to develop practical recommendations for increasing the level of digital business transformation index based on clustering of small and medium enterprises.

Subject of research: development and use of practical recommendations (digital roadmaps of digital transformation) for entrepreneurs.

Research methods used: survey of entrepreneurs, analytical methods for determining the Index, statistical methods of data processing, expert analysis of respondents' answers, cluster analysis of business structures, business analytics.

Results of the research. The list of multilevel recommendations for increasing the Digital Transformation Index were formed as well as the calculation method of the Index were described. Also was displayed gradation of recommendations; the results of clustering of business structures by the level of digital maturity were demonstrated; specific recommendations for raising the HIT for the enterprises of each of the clusters were formed. Such a methodology should take into account the current state of affairs in Ukraine, reflect an in-depth analysis of the level of digital transformation of business structures, while being flexible in order to respond promptly to new phenomena and the emergence of new digital technologies.

Keywords: Digital Transformation, Clustering, Index of Digital Transformation of Business Structures, Digital Transformation Roadmaps.

1 Introduction

At present, the transition of the industrial economy and the information society to the concepts and requirements of the "digital" economy is actively taking place. Such radical transformations require a new approach to understanding the nature and consequences of these processes, as well as the ability to adapt digital technologies to the contemporary demands of society and business. The rapid adaptation and transformation of business structures in the digital sense is one of the key tasks for raising the competitiveness of the domestic economy as a whole and integrating it with the leading global economic system.

The process of digital transformation of a business structure involves the transformation of its business strategy, models, operations, goals, marketing approaches, etc.

in the direction of increasing use of digital technologies [1]. Beside these management and strategic changes digital transformation also includes usage of industrial automated systems which help in manufacturing such as automatic robots, manipulators, augmented reality etc. Also, cybersecurity should be mentioned as a one of most important aspects in the implementation of the principles of digital transformation.

However, in Ukraine, such processes are slow. The problem is the lack of entrepreneurs with the necessary knowledge regarding the use of innovative digital technologies [2]. There are also no platforms, services or applications to explain the importance and potential of using digital tools in business transformation.

Insufficient awareness of entrepreneurship about the ability to integrate technology into their own business processes causes retardation of development of companies and difficulties in the entry of domestic business into the international arena. That is why along with statistical studies of the use of information and communication technologies in business and shaping the positions of companies in the process of digital development of the country, it is an important task to create roadmaps for digital transformation and to provide recommendations on opportunities to use digital tools and increase digital literacy of both entrepreneurs and the population in general.

The purpose of this work is to provide a list of common multi-level recommendations for the indicators defined by the Digital Structural Transformation Index of Business Structures proposed in [3].

The problem of the development of digital economy and transformational processes taking place in society under the influence of digitization has received a lot of attention among both foreign authors [4-8] and Ukrainian researchers [1-3, 9-12], etc.

Despite numerous scientific studies on the development of information and communication technologies and the digital economy, we believe that the issues of the impact of digital technologies on business transformation are under-researched.

2 Features of the digital business transformation index (HIT)

2.1 Concept of Digital Business Transformation Index

The creation and use of the Digital Business Transformation Index was proposed as one of the methods for assessing the level of digital development of small and medium-sized enterprises (SMEs). If applied as a national methodology, it will be possible to evaluate the digital maturity of business structures and provide recommendations for improving it. This method allows to take into account sufficient indicators of impact on the development of business and the information society as a whole.

Regular calculation of the Index for a specific business structure can be used as a tool for monitoring and evaluating the performance of a business using digital tools. This will help identify the problem areas in the development of SMEs and will at the same time form a transformation vector with the aim of integrating domestic business into the global digital economic system.

The baseline statistics used to develop the methodology for determining the Digital Transformation Index were collected through a questionnaire that included 4 groups of indicators: informative, digital indicators, use of digital tools, and digital human literacy [3]. For the direct calculation of the Index, the last three indicators are used, namely:

- indicators of the enterprise digital infrastructure, which describe the level of its provision with the necessary equipment (personal computers, laptops, smart phones) and broadband Internet;
- the use of digital tools is a key indicator that represents the qualitative characteristics of the effectiveness of technology in business. This indicator includes components such as use of social media management (SMM), site functioning and search engine optimization (SEO), work with specialized systems for business process automation, etc.;
- digital literacy (competence) of human capital, which is defined as the ability of an employee to perform complex tasks and requirements, involving both professional and personal skills [15].

It should be noted that digital competence has been recognized by the European Union as one of the 8 key competences for a fulfilling life and included in the updated Digital Competence framework created by the EU [16; 17]. Due to the three main components used to determine the level of digital transformation of business structures - Human Resources, Digital Instruments and digital Technologies, the generalized three-component Digital Transformation Index has been known as “HIT”.

The first, an informative indicator that gives an overview of the company, its business scope and the ability to use certain tools according to its specificity and needs, was not used to calculate the Index.

2.2 Mathematical basis for HIT index calculation

Using summary structural indicators of digital transformation, the authors proposed in [3] a formula for determining the generalized Digital Transformation Index of a business structure (1):

$$HIT = Summ_H \cdot \omega_H + Summ_I \cdot \omega_I + Summ_T \cdot \omega_T, \quad (1)$$

where «HIT» – Digital Business Transformation Index;

$Summ_H$ – summary of the digital literacy of the human capital of the organization;

$Summ_I$ – summary of the status of the use of digital tools in the business processes of the organization;

$Summ_T$ – summary of digital technology usage in a business organization;

ω_H – weight factor indicator H;

ω_I – weight factor indicator I;

ω_T – weight factor indicator T [3],

$$\omega_H + \omega_I + \omega_T = 1 \quad (2)$$

Separate indexes of the Index are determined by (3):

$$Summ_X = \sum_{i=1}^m n_i^{(X)} k_i^{(X)}, \quad (3)$$

where m – number of components of the indicator X ,
 $n_i^{(X)}$ – meaning of I component indicator, $n_i^{(X)} \in [0;1]$,
 $k_i^{(X)}$ – weight factor indicator, $n_i^{(X)}, k_i^{(X)} \in [0;1]$.

The contribution should contain no more than four levels of headings. The following Table 1 gives a summary of all heading levels.

Table 1. Table captions should be placed above the tables.

Metric range	Level
$Summ_X \in [0, 0.2]$	very low
$Summ_X \in [0.21, 0.4]$	low
$Summ_X \in [0.41, 0.6]$	average
$Summ_X \in [0.61, 0.8]$	high
$Summ_X \in [0.81, 1]$	very high

Obviously, with the introduction of these restrictions for an arbitrary j business structure will be implemented

$$HIT \in [0,1]. \quad (4)$$

Using formula (3), the values of the three main consolidated indicators were obtained, which are important components not only for calculating the numerical value of the Business Transformation Index, but also for providing recommendations to companies to improve the Index.

2.3 Creating a list of multi-level recommendations

As mentioned above, the recommendations are a kind of a “roadmap” for the digital development of small and medium-sized businesses, as they allow to specify own digital transformation vector for an individual company or group of companies. At the same time, the availability of recommendations makes it possible to monitor the effectiveness of the implementation of digital technologies in business processes in view of the annual change of the Index and its constituent indicators. Taking into account the results of the research [11], [12], the authors developed recommendations for different levels of each of the three main indicators listed in Table 2.

Table 2. List of multilevel recommendations for increasing the HIT index.

Indicator	Number	Value	Recommendations for different levels
H	1A	0...0.2	Introducing employees to basic digital tools: user-level social networks, messengers, office applications
	1B	0.21...0.4	More advanced level of working with social networking: creating business pages, systematically filling out these pages. Using targeted sites, viewing articles, video tutorials, online beginner courses. Practicing digital skills, training employees. Introducing a separate Digital Specialist position (if required).
	1C	0.41...0.6	Training company employees (at beginner courses) in the desired field: marketing, SMM, SEO, design, Human Resource Management (HR), Customer Relationship Management systems (CRM), advertising and more. Analyzing trends in your industry, monitoring competitors in Ukraine and abroad, learning ideas, experiences, analyzing their mistakes.
	1D	0.61...0.8	Consultations with professionals in specific fields of digital technology: marketers, targeters, copywriters, designers, pay per click specialists (PPC), CRM specialists and other systems. Outsourcing of specialists is possible, experience of employees of the company, attending conferences.
	1E	0.81...1	Attending company specialists for professional conferences or events, participating in targeted webinars or online courses, improving skills, in-depth analysis of trends and their production.
I	2A	0...0.2	Use of basic digital tools: social networks, messengers, online documents; creation of an enterprise site, digitalization of communication with clients (communication via e-mail, messengers, form on the site, etc.).
	2B	0.21...0.4	Improvement of digital competences of personnel, transition to business use of social networks, partial digitization of business processes, positioning of a company in a social network, automation of communication with clients (chatbots, QR codes).
	2C	0.41...0.6	Performing SEO-optimization of your own site, starting to use advertising campaigns on social networks, creating content plans for systematic work, use of CRM-systems and financial management systems, increase of digital competencies of the personnel, partial introduction of data collection analytics.
	2D	0.61...0.8	Professional use of social networks and their advertising offices, involvement of specialists. Use of online analytics data for decision making and Business Process Management systems (BPM) to model and automate business processes. Introducing digital systems for staff training. Creating a strategy for promoting a company on social networks and adhering to it. Use of corporate messengers (if necessary).
	2E	0.81...1	Use of statistical analysis and projection technologies (Data Mining, Big Data, Predictions), working with analytical applications for Supply Chain Management (SCM) and Product Data Management (PDM) and Enterprise Resource Planning systems (ERP). Working with 3D - printing, product location tracking, geoinformation systems (if needed)
T	3A	0...0.5	Providing the minimum necessary amount of computer and mobile equipment in the enterprise, concluding agreements with ISPs and service centers, solving existing problems.
	3B	0.5...1	Maintaining a satisfactory state of the equipment and technology, and gradually upgrading or increasing its the number, if necessary.

It is worth noting that the recommendations cover both improving the company's technical support and enhancing the professional level of employees and expanding the integration of digital tools into the company's operations. In addition, the recommendations given for "very low", "low" and partially "average" levels of indicators often do not require additional financial costs for software purchase or staff training. At the same time, tasks that are defined at a "very high" level of performance often involve the use of specialized technical and information tools, which may not be relevant for a large part of business areas.

3 Research results

3.1 The results of the clustering of respondents

In order to develop a common methodology for providing guidance to SMEs, business entities were clustered according to their level of use of digital technologies and tools in their activities [3]. Clustering was performed according to the results of the survey, described at [11]. Participants were representatives of SMEs of various industries in Ternopil region including private schools, dentistry, cafes, manufacturers of industrial goods, IT-businesses etc. Also, it should be noted that clusters were formed without taking into account division by industry and were based only on calculated efficiency of three indicators described above.

As a result, 5 stable clusters were identified with the following characteristics:

- Cluster I: companies that have no experience in usage of digital technologies;
- Cluster II: companies with the limited use of only one tool, social networks, namely;
- Cluster III: companies using more sophisticated digital tools;
- Cluster IV: companies that use some digital tools of their own (SEO, social networks, advertising);
- Cluster V: companies that use almost all advanced digital technologies, including Data Science techniques.

Equation (4) summed up values for each indicator for all respondents. For example, the values for Cluster 4 participants are shown in Table 3.

Table 3. The value of the Digital Transformation Index for the respondents.

Cluster	$Summ_I$	$Summ_T$	$Summ_H$
IV	0,341	0,767	0,4
	0,338	0,684	0,6
	0,261	1	0,8
	0,453	1	0,6
	0,488	1	0,8

The ordered triple $(Summ_I, Summ_T, Summ_H)$ of the numerical values of the indicators for each individual enterprise can be represented by a point in the three-dimensional coordinate system, where x-axis denotes the level of use of digital tools ($Summ_I$), y-axis – availability of digital business infrastructure ($Summ_T$), z-axis – digital literacy of human capital ($Summ_H$). Since the values of all indicators belong to segment $[0;1]$, all points will be placed in a cube with edge $a=1$ (see Fig. 1).

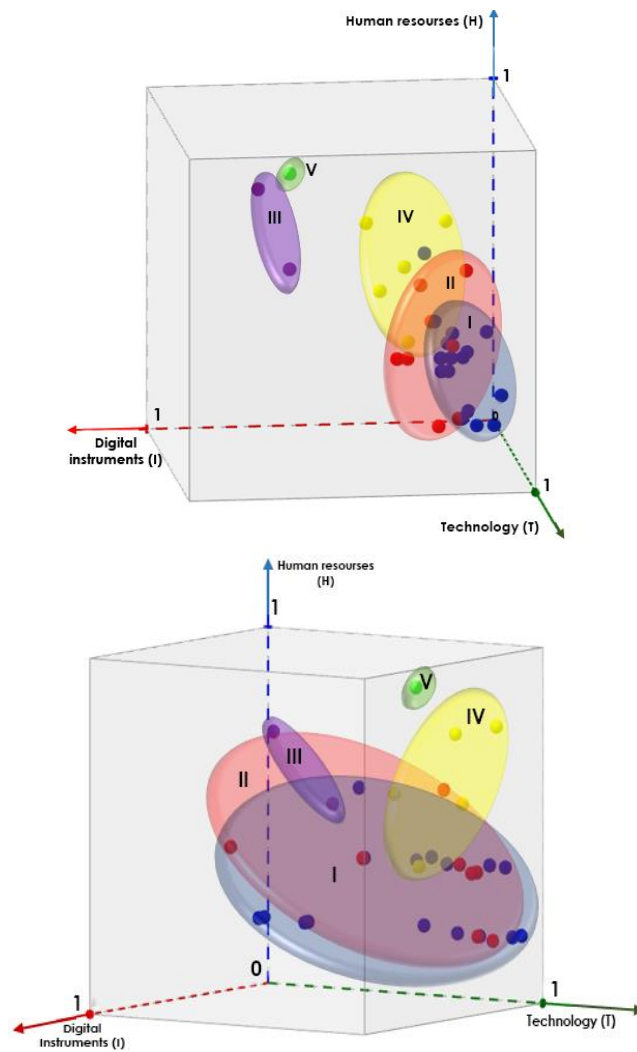


Fig. 1. Visualization of respondents' clustering results (two projections).

Fig. 1 illustrates the results of the division of SMEs into clusters. The spatial rectangular coordinate system shows two projections of the cube of all possible locations of

points. The clusters formed are shown as ellipsoids of different colors, the points inside the ellipsoids indicate separate business structures. The closer the point to the origin (O point) is, the weaker is the business structure in digital terms.

As we can see from Fig. 1, clusters V and III have the largest values in the coordinates H (human capital) and I (digital instruments), which is why they are quite different from the others. With respect to the T (technological support) coordinate, a wide spread of points can be observed for clusters I and II (values in the interval), but by the X coordinate they are rather tightly grouped in the region of the origin of the axis. Cluster IV is close to zero with respect to the x-axis, but in terms of human capital development it is higher than clusters I and II, and the points are distributed fairly tightly with respect to y-axis.

3.2 Providing cluster recommendations

Taking into account the peculiarities and distinctive features of the individual “clusters” of business structures resulting from clustering, the authors developed specific recommendations from Table 2 for each individual group of enterprises. The intervals of indicators and the reference numbers for each cluster are shown in Table 4.

Table 4. Providing recommendations by cluster of respondents.

# cluster	Number of participants	H	I	T	Recommendation numbers
I	16	0.2...0.6	0.05...0.26	0.07 ... 1	1B/1C, 2A, 3A/3B
II	10	0.2... 0.6	0.174 ... 0.4	0 ... 0.9	1B/1C, 2B, 3A/3B
III	2	0.6... 0.8	0.669... 0.74	0.5 ... 0.67	1D, 2D/2E, 3B
IV	5	0.4... 0.8	0.261... 0.49	0.684 ... 1	1C/1D, 2B/2C, 3B
V	1	1	0.712	1	1E, 2D/2E, 3B

It should be noted that only general management, marketing and strategic recommendations are considered in the research whereas industry solutions may vary between companies which have different work areas. Such solutions may be offered and implemented only by industry experts in specific area, so this is a separate topic for work and research.

The general recommendations for each of the clusters can be worded as follows:

1. The following measures are recommended to the first cluster:

- practicing basic digital skills of all enterprise employees and developing the professional skills of employees who work directly with digital technology through offline and online courses;
- using basic digital tools: social networks, messengers, online documents, design platforms;
- providing workers with the required amount of digital technology.

2. The measures recommended to the second cluster are:

- to practice basic digital skills of all employees of the enterprise, and the development of professional skills of employees who directly work with digital technologies through offline and online courses;
- after increasing the volume of work on social networks and platforms, to distinguish the position of SMM-manager / internet marketer / digital specialist, etc.;
- to transition to more complex use of social networks, regular content creation, automation of communication with clients through chatbots, QR codes, etc.;
- to provide the required amount of equipment and keeping it up to date.

3. Businesses that are referred to the third cluster are recommended:

- conducting an external audit of the quality of the use of digital tools, if necessary, consult with professionals in the chosen field;
- following trends in the industry, attending conferences, taking on the experience of competitors and trendsetters;
- creating a strategy for positioning the company in the Internet space, using analytics data for decision-making and specialized systems to fully automate business processes;
- using statistical analytics and forecasting technologies, industrial robots, sensors, etc.;
- keeping hardware and software up to date.

4. The representatives of the fourth cluster are recommended:

- training responsible for the use of digital technology by company employees on offline or online courses in the required topics, creating a post of SMM-manager / internet marketer, etc.
- analysis of industry trends, lessons learned from competitors or brands in related businesses, consulting with professionals about the challenges and opportunities of using a digital tool;
- positioning the company on social networks, creating regular content and publishing it according to the content plan, start using advertising campaigns on social networks;
- automation of communication with clients by means of chatbots, QR-codes, etc., SEO optimization of the site;
- use of CRM systems, financial management systems, connection of analytical tools and start of data collection;
- keeping hardware and software up to date.

5. The following measures are recommended to the fifth cluster:

- continued professional development of company specialists, attending highly specialized conferences, events, courses and webinars;
- deep analysis of trends of own and related industries, rapid response to topics of peak popularity, analysis of competitors' mistakes;

- create and adhere to a strategy to promote and build brand or company loyalty, refine strategy, actively use a large number of digital tools and analytics data;
- when using Data Science, statistical analysis, forecasting, geo information systems and other sophisticated technological tools;
- keeping hardware and software up to date.

An analysis of the list of specific recommendations developed to increase the level of complex digital maturity of business structure clusters has shown that most of the proposals are aimed at increasing the digital literacy of company employees and increasing the share of digital tools used. It should be noted that low digital literacy (H) results in low technology usage and business process digitalization (I). This is due to the fact that staff who do not have sufficient knowledge of the use of computer technology at the user level, cannot effectively use even the simplest tools: social networks, online documents, etc. and independently solve creative business tasks. An example is the first cluster in which the indicated level of digital literacy of staff ranges from 0.2 to 0.6 (low-to-average level of subjective assessment of the manager), but the level of use of digital technologies is at the lowest. At the same time, in the third cluster, digital literacy was rated in the range of 0.6... 0.8 (high level), and therefore the use of digital tools is in the same range.

In contrast, the level of computer hardware provision has little effect on the success of modern technology, since most companies have enough equipment to use most digital tools.

One way to solve the problem of low digital literacy of staff is to educate all employees in terms of the basics of digital tools, assign positions for professionals who will be responsible for the use of technology in enterprises, and develop their professional skills.

4 Conclusion and future works

The result of this study is to develop a list of common, multi-level recommendations to small and medium-sized businesses in order to increase three indicators of digital maturity: the use of digital technology in company operations, the integration of digital tools into business processes, and the level of digital competence of employees. Based on previous research on clustering of interviewed entrepreneurs of Ternopil region and formulation of the concept of digital transformation of business structure, each of the groups of respondents was advised to improve the value of the components of the Index to the next level.

Providing guidance on improving digital business metrics will allow small and medium-sized businesses in Ukraine to choose the right vector for developing groups of companies with similar metrics. Dissemination and acceleration of digital transformation of business structures will positively influence the digitization of society in general and the integration of domestic companies with the advanced global digital economy.

Future research plans to outline a list of personal recommendations for each respondent, depending on their current status of use of digital tools and needs for busi-

ness activities. These guidelines will create individual development vectors for companies to increase competitiveness in both the domestic and global business space, as well as monitor and strengthen their weaknesses and remove barriers to further development.

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Integration of Delivery Services Business Cases for improvement of Business and Environmental Sustainability of E-Commerce Solutions

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Abstract. Nowadays society is tangible to introduce and widely support sustainable technologies and systems especially if they are involving a high level of various services integration. As E-commerce systems are playing a major role in our life the current work aims to analyze the sustainability of different levels of delivery services in combination with return exchanges, automated ordering, replacement retrieval, and even recycling of old items supported. The bright example of automated services implementation will be made with the involvement of real cases implemented in contemporary international eCommerce systems with the possibility to simulate how organizations can adopt additional services, attractive to B2C and B2B users. The analysis of usability and cost-effective parameters indicates the distinction of applied approaches in companies with different incomes and infrastructure indicating how the level of integration enables the company to become more sustainable and environmentally friendly. The work reviews the infrastructural composition of the contemporary E-Commerce system and its implication on the level of sustainability of the company itself and the environmental impact the sustainable development may do to an E-Commerce application. The work reviews the results of the impact evaluation on the financial and sustainable parameters of the models related to different organizations.

Keywords: customer behavior; usability evaluation; e-commerce, environmental, and business sustainability.

1 Introduction

1.1 Formulation of the problem.

When someone first hears about E-commerce at that very moment the person thinks of emotions that are coming to us and bring positive impressions of the design, colors, attractiveness, suggestions and best experience ever that may be potentially developed by electronic means and human experience; supported by customer success teams working hard to make the application successful.

At the same time, it is well known that each E-commerce system is the highly intelligent integration of subsystems, that are designed to serve and cut corners of possible overpayments and over-storage bringing ease of logistics, effective analysis and thorough filtering of the search results and intelligent faceting. All these integrated parts were highlighted in various publications [1-3], indicating benefits and possible improvements of approaches to apply subsystems or web-services, and above all, the most important studies investigated the verification segments and statistical information related to the particular study.

Thus far mankind does not associate E-Commerce with Sustainable environments due to overproduction that is involved in Manufacturing systems, that feed E-commerce with stocks and assortments, and whatever is not sold in the E-commerce system may still be dusting in regular stores and waiting for the customer in search of End-of-Life products. Nowadays the E-commerce systems are serving better to sell and take better care of End-of-Life products offering them in the separate aggregators and platforms offering maintenance and refurbishment services. All of them are different facets of the sales process, that aims at the quicker turnover and cleaning up the stock. In the context of overproduction, over-purchase - the support of returns and recalculation of sold "used items" back to the vendor will keep the balance of sustainability of E-Commerce platforms. Besides, the sale of used products make the platform even more sustainable, however, this should still be properly traced through the funnel of how the item comes from manufacturer to the customer, come in use and then returns to the manufacturer for revitalization, refill, refurbishment, renovation or recycling.

Many reviewers estimated U.S. online retail sales were \$97.3 million in second-quarter 2016, a 15.8% increase from the previous year, and at the same time the number of possible returns is not even counted here. According to Forrester, that growth is expected to continue with U.S. online retail sales anticipated to exceed \$520 billion by 2020. Globally, online sales are growing three times faster than GDP [4]. According to the 2016 UPS Pulse of the Online Shopper study, 38% of purchases combine store visits with online research or purchase, and half of the surveyed respondents ship purchases to regular stores for pickup. Adding to this mix is a trend toward recurring deliveries. For more predictable items, consumers are increasingly willing to trust automatic refills, where one request results in ongoing fulfillment.

Ukraine, Europe, and US markets are sharing the same trends in the investigation as the market analyzed mainly based on ERP-based E-commerce systems, thus the

subject of the current study is focused on a review of the sustainability processes for E-commerce system analyzing the trends of the retail channels.

The purpose of this paper is to describe the experience in the development of different approaches for tracking the packages from the perspective of usability, sustainability, and customer satisfaction, which results in the client's retention.

1.2 Analysis of recent research and publications.

The solution proposed is aimed to investigate the closed-loop of e-commerce processes, help vendors and increase the trust of users into the delivery services using better insight into what route the parcel takes to get to the final destination.

To cover this multidisciplinary approach let us disclose the existing relationships between e-commerce investigations made for shipments deliveries [3], including domains of domestic deliveries [4], customer purchasing habits [6-8], improvement of usability experience to create the trust of users to the delivery channels and be ready to cover the operating expenses related with automation.

The authors highlighted the approach of integration of delivery [2] were combined with the e-commerce solution with API services provided at the existing market. Overlapping of that work with publications of Routhier (2013) and Morganti and Dablanc (2014) uncovered the city and outside city delivery approach covering the transportation perspective and possible ways of further optimizations in that domain. Authors constantly suggested considering the direct and combined approaches of using the transportation system to optimize the time of delivery, however, the time is not always leading to a cost-effective solution.

Reichheld and Schefter (2000), Abrham et al. (2015), Zelazny (2017) or Ehrenberger et al. (2015) observe that there is a significant relationship between long-term growth of companies' profitability and customer purchase intention [13] however that indicated a good insight that analyzing mid-size companies and trace the turnover and orders circulation it will be easier to identify the dependencies between the options people usually chooses and possible shipment options the current vendors can offer.

Applied approaches were projected to the constantly ongoing process of e-Commerce applications improvements and its reflection to sustainable solutions that close the loop of e-commerce turnover and that should cover the main challenges of contemporary e-commerce systems.

2 The method

Day-by-day web-shops are selling more items that are produced and assembled with higher technological parts or processes, that increase the impact on the environment. More and more people are requesting the items be delivered from the internet platforms, so, the simple click "Add to Cart" that starts the full chain of transformations in E-Commerce systems and processes

The demand for a seamless shopping experience positively influences visitors and customers however merchants now face challenges of offering faster and easier shipping and return options, as well as the growing expectation that returning an item should be as seamless as receiving and as convenient as a simple handover. If the returns process is harsh, the customer experience level drops, and what started to be a satisfied consumer soon becomes a frustrated one [4].

The below diagram indicates the subsystems of the contemporary E-Commerce platform, that integrates a lot of external Software vendors offering services (fig 1.).



Fig. 1. E-Commerce system components integration.

As retailers deal with an ever-increasing number of packages that must be delivered in minimal time and remain competitive and profitable while also reaching customers across channels in the most effective, efficient, and sustainable in pre-order and post-order processing periods. The delivery of e-commerce products has reached unexpected heights in the last few years. Most deliveries made with e-commerce consist of parcels, small packages, and food containers. Forrester Analytics builds the trends that the share of online retail will continue to grow steadily in the next years in the US [1]. Deliveries may have a variety of options like collection points, pickup locations, or direct delivery to the customer location.

With goods flowing in multiple directions among manufacturing facilities, warehouses, stores, and consumers, traditional supply chain models are insufficient. The workload of the online shop team is entirely packed. Every day the web-shop or any other online service operational employee collects items for an order then carefully packs them and sends via delivery service to the end-users. The great ease of this brings the online rate shopping tools that can calculate the costs precisely. With the variety of different vendors carriers and modes of delivery, the end-user may choose between cost speed and flexibility.

E-commerce brings new considerations on standard processes from packaging and fulfillment to returns, as well as new possibilities to create and implement innovative and sustainable solutions. Businesses are partnering with logistics providers to reduce impact and improve the effectiveness of operations.

It is known that the variety of consumer-friendly services available, like UPS, USPS, DHL, FedEx allow residential customers to choose and possibly even modify their delivery times and locations, as well as provide access to an extensive network that supplies customers with new ways to receive deliveries at an alternative location – especially important for deliveries to apartments or other locations [5-7].

These services help online shoppers avoid missed deliveries and eliminate the environmental impact associated with wasted trips caused by multiple delivery attempts.

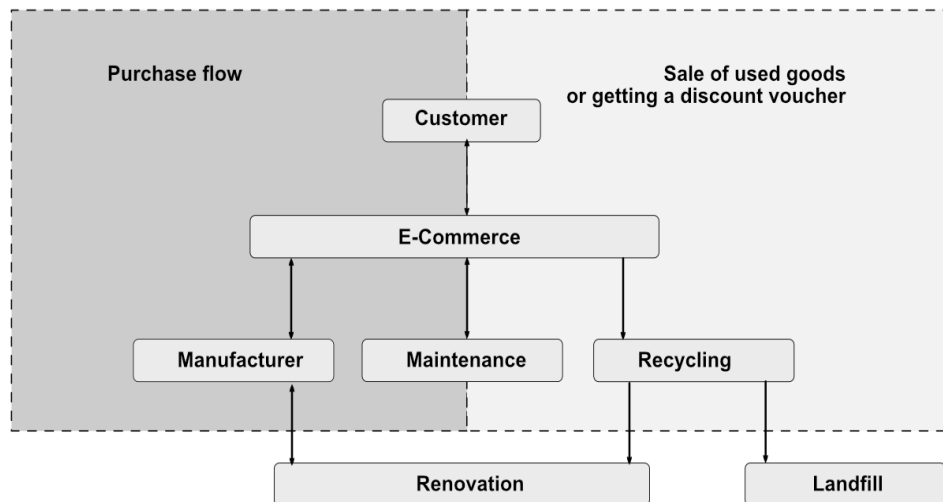


Fig. 2. The closed-loop approach of sustainable E-Commerce solution.

Another area worth taking a closer look at its packaging. Properly packaged goods have a better chance of arriving intact, reducing the number of returns and the overall environmental footprint. When a shipment is packed correctly and arrives undamaged, no replacement goods need to be picked, no additional transport is required to replace the item, and no broken items have to be managed, recycled, or

sent to a landfill. Packaging made from sustainable materials also helps to further reduce the environmental impact and reduce waste, while demonstrating to customers that the company is using best practices [8].

And it's not just large companies that are committed to navigating e-commerce sustainably. Small businesses are also using smart partnerships to enhance sustainable business practices. The company now uses shipping boxes made of recycled cardboard that are right-sized to prevent the use of excess materials, and crush tested to prevent product damage, as well as to reduce the rate of return shipments. Additionally, many companies ship orders via carbon-neutral, where carbon offsets are purchased to balance out the emissions produced by the transportation of shipments [9-11].

Along with environmental problems important business aspects are improving: customer satisfaction, brand attractiveness, trust, and turnover. Environmentally friendly companies are becoming more and more popular in the environmental caring world. Besides the payments companies have to incur are highly dependent on the usage of landfills for many countries. In addition to this, the logistic component of delivery has an indirect impact on the CO₂ emission problem which is relatively connected to transportation growing these days, however, this is not the main subject of the current paper.

The most important approach of the closed-loop indicated in fig. 2 highlights the closed cycle of delivery of goods to the customer and in case of repair or renovation or simply recycling – the same chain is used. It increases the trustworthiness of the client to the service, the distribution networks, and have a lot of other positive effects.

Here are a few ways retailers can navigate the changes taking place to boost their sustainability factors:

1. **Optimization of delivery chains.** Businesses evolving to meet the demand for e-commerce must re-evaluate current delivery chains that were created to support in-store and clients' deliveries. Using the same channels E-commerce brings novelty applying return deliveries for product returns.

This slight improvement brings ease for new ways of improvements for fuel reduction if the carrier can bring packages and fetch returns at the same time keeping the environment healthy [12].

2. **Investigating user's habits.** The flow of goods throughout delivery chains generates analytical data and recurring deliveries impact the merchant's accounts giving more and more discounts in the future. By partnering with a logistics provider that can tap into the power of this data, retailers can gain insight into customer preferences and trends, learn about hidden issues (e.g., ineffective processes or packaging), and fine-tune supply chain movement so that valuable assets such as resellable returns don't get lost or overlooked.

3. **Flexibility on logistics.** Collaboration and innovation of the user's habits may lead to a shift in logistics. Simple steps, such as providing customers with a way to shift their delivery to a time and location that meets their needs, reduces the environmental impact and results in a better experience for everyone [13].

4. Bonus programs and compensation for goods recycling. More and more companies are collecting the remaining emissions. This, in turn, demonstrates company concern that goes beyond capturing immediate revenues. This type of positioning can help support the company's reputation and offer a competitive advantage when driving consumer preference.

The cultural shift to e-commerce has brought about new expectations for immediate gratification from consumers, and with that, increased environmental impacts as retailers attempt to meet those demands. However, when companies are willing to invest in creating sustainable solutions to navigate the evolving demands of today's shopper, they will see a return on their investment beyond operational efficiencies.

Scientific and educational aspects of measurements of real-time systems that are usually used for investigation and how companies are added to that.

Let us combine these possibilities and review the case-study of implementation of the use-case for order delivery with and without tracking of its delivery as a demonstration of customer trust to the delivery systems and its application for returns.

Analysis of the feedback channel will uncover the results of the use-cases applied in the group of companies selling similar items in the period of 2-years.

3 The approach

Let us focus on Post-order processing involves the monitoring activities especially on tracking and tracing of the parcels. Both B2B and B2C segments have activities. For the closed-loop of the delivery process and return delivery, we may review the assignment of the return order of items recently delivered.

Let us create several business cases:

- Simple order implementation;
- Order implementation with the tracking number;
- Order with multiple links and listing of bypassed stages of delivery;
- Order tracking with the GPS;
- Return order tracking.

Post-order processing involves the monitoring activities and Tracking or tracing of the parcels.

Simplistic implementation of the order details page with mentioned shipping costs have the lowest level of usability from the standpoint of order tracking. In such conditions, the highest load will be to the customer support team to respond to all requests of orders with the reference to the Order Number for each submitted document.

ORD-1711000005 ORDER

Order no.	ORD-17110600005	Order date	02/6/2020
Order status	Delivery in progress	Payment method	Pay Pal
Shipping Carrier	DHL	Payment terms code	
Shipment date	02/7/2020	Due date	02/09/2020
Sell-to-contact	Frank Collinson		

SELL-TO ADDRESS

Daughter Emily via
 Frank Collinson
 1156 N. 6th Street
 Brooklyn, NY 12345
 United States

SHIP-TO ADDRESS

Frank Collinson
 128 N. Victory Street
 Stemford, CT 24345
 United States

Item No.	Title	Status	Ship. d.	Price	Qty	UOM	Ship.	Inv.	Outst.	Total
AB122348	Product name	Not shipped	11/7/2017	\$ 1.127,95	1	piece	0	0	1	\$ 1.127,95
									Subtotal	\$ 1.127,95
									Invoice discount	\$ - 37,57
									Shipping costs	\$ 50

Fig. 3. Examples of the standard order with calculated shipping costs.

Posted order in the E-Commerce system contains the list of items, that can be rate-shopped either via flat fee for shipping costs or rate-shopped at Delivery service. The image above indicates that the order has indicated shipping costs of 50 USD, however, that does not have the tracking indication at the order.

The example of better implementation of usability towards user tracking is posting the tracking number indicated in the order header are indicated in fig.4.

ORD-171100005 ORDER

Order no.	ORD-1711060005	Order date	02/6/2020
Order status	Delivery in progress	Payment method	Pay Pal
Shipping Carrier	DHL	Payment terms code	
Shipment date	02/7/2020	Due date	02/09/2020
Sell-to-contact	Frank Collinson	Tracking code	D1578922355 D1578922356

SELL-TO ADDRESS	SHIP-TO ADDRESS
Daughter Emily via	Frank Collinson
Frank Collinson	128 N. Victory Street
1156 N. 6th Street	Stemford, CT 24345
Brooklyn, NY 12345	United States
United States	

Item No.	Title	Status	Ship. d.	Price	Qty	UOM	Ship.	Inv.	Outst.	Total	
AB122348	Product name	Not shipped	11/7/2017	\$ 1.127,95	1	piece	0	0	1	\$ 1.127,95	
										Subtotal	\$ 1.127,95
										Invoice discount	\$ - 37,57
										Shipping costs	\$ 50

Fig. 4. Examples of the order with several tracking links for an order of E-Commerce system.

Costs related to the API call to the shipment provider are negligibly small but significantly increase the accuracy of the costs calculation and appropriate subtotals, totals, and tax calculation. The above case is the most simplistic implementation that involves only the programming costs and integration with an ERP. It is recommended to remember the license costs, that cover the updates of the system itself keeping your application healthy.

This goes without saying that demanding clients will expect compensation of additional parcel tracking via the client phone line, so, in case you have the voice chat or integration with the Client Support System keeps the best experience. However, looking into the Google Analytics and Extended analytics with heat-maps indicates that orders are just reviewed to make sure all the items are in it, however not traced from the delivery standpoint. See the user experience of tracking ID transformation into the link, that leads to the site of the Shipping provider, where the customer may see the latest route point for a parcel, fig. 5.

ORD-1711000005 ORDER

Order no.	ORD-17110600005	Order date	02/6/2020
Order status	Delivery in progress	Payment method	Pay Pal
Shipping Carrier	DHL	Payment terms code	
Shipment date	02/7/2020	Due date	02/09/2020
Sell-to-contact	Frank Collinson	Tracking code	D1578922356

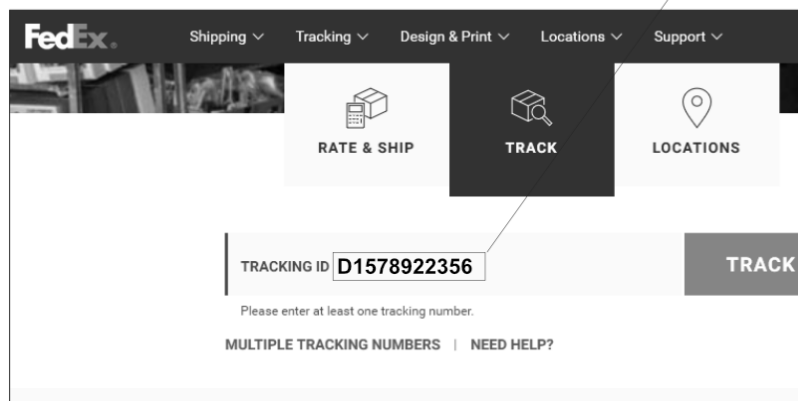


Fig. 5. User experience for order tracking with the link to the shipping provider.

Contemporary shipment providers are keen to update the delivery date depending on the situation at the roads and may update the shipment information from the carrier directly in case of appropriate integration. The use-case of the above order is not reflecting this possibility and a great deal of these problems is the absence of solution integration with the shipping provider. The above case indicates semi-integrated solution where the order tracking number may be assigned in the ERP system directly and further reflected in the E-commerce solution, where the client may either click the link and be delivered to the web-site of a vendor or retrieve the list of points the parcel bypassed directly into the E-Commerce control of the Shipment Provider (fig. 6).

To close the sustainability loop of the production process authors decided to generalize the recent approaches and suggested using the latest solution for tracking the return order. As the item that belongs to the client acts as a sort of a possible future discount for the next order, tracking of the delivery should have the maximum comfort.

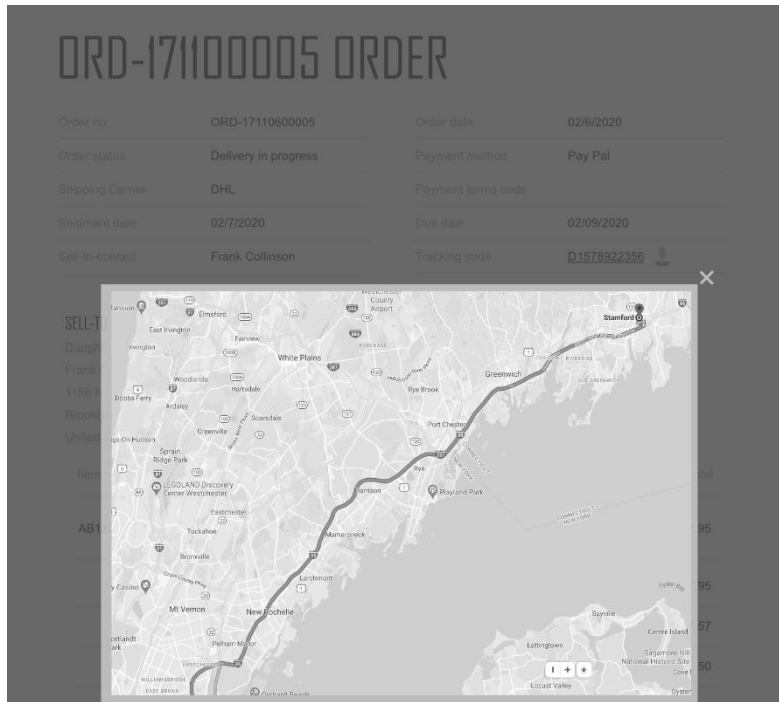


Fig. 6. Example of tracking number assignment for single package order.

See the suggestion of the return order at the fig. 7.

1711060005 POSTED RETURN RECEIPT

Document no.	1711060005	Order date	02/09/2020
Order number	ORD-1711060005	Document date	02/09/2020
Shipment date	02/10/2020	Due date	11/7/2020
Sell-to-contact	Frank Collins	Payment discount	0
Reference no.	EXT DOC NO 019283746	Tracking code	D1758212367

SELL-TO ADDRESS

Daughter Emily via
 Frank Collinson
 1156 N. 6th Street
 Brooklyn, NY 12345
 United States

SHIP-TO ADDRESS

Frank Collinson
 128 N. Victory Street
 Stamford, CT 24345
 United States

Item No.	Title	Status	Ship. d.	Qty	UOM	Outst.
AB122348	Product name		11/7/2017	1	piece	1

Fig. 7. Return Order with the tracking-number link, that leads to the GPS tracking map.

4 Results

Looking into Google Analytics and Google Tag Manager it easy to identify the trend of implementation of tracking services and Map integration seriously increases positive feedback and Net Promoters Score of the company.

The authors decided to validate the number of orders submitted by each AB testing and real orders collected by the companies implementing the approach. The only data missing in this comparison are returned orders, however, they are closing the sustainability loop and are more interested in validation of the approach.

Below is provided the analysis of costs involved for implementation of the above use cases (fig 9.)

An interesting case is that comparison of Order tracking and Returns tracking confirm the interest of the audience of getting faster rewards or discounts.

The fact is that impatiently waiting for the order client increases the frequency of visits. However, for Return orders' tracking visits the client is tracking 2 places: where the parcel is delivered and if the discounted rate is added to the account.

Additionally, the analytics disclosed the interesting fact: the trend of returns increased for those platforms, which have good delivery/logistic support with a maximum of integration and respective configuration of the recycling mechanism supported. People are happy to form the return of the old items to get discounts on the new items.

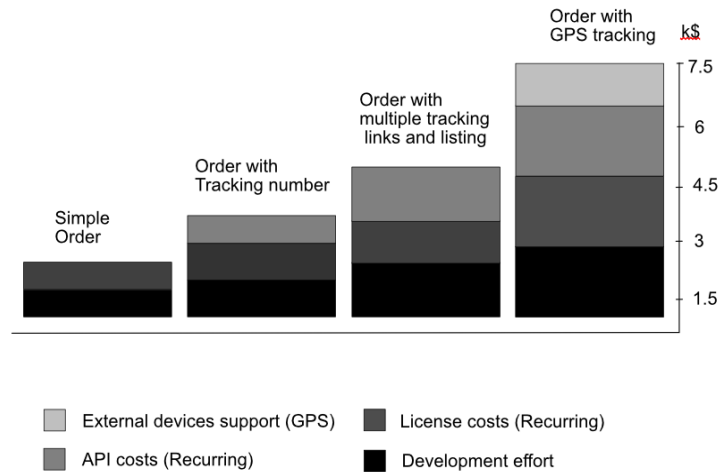


Fig. 8. Costs analysis of use-cases from the perspective of costs involved.

Additionally, the analytics disclosed the interesting fact: the trend of returns increased for those platforms, which have good delivery/logistic support with a maximum of integration and respective configuration of the recycling mechanism supported. People are happy to form the return of the old items to get discounts on the new items.

Looking into the NPS score for 4 cases and their projections to the companies we can compare the NPS score gain within 1 year of implementation as presented in table 1.

Table 1. Customers' satisfaction and NPS score review for NPS range 1-10 for 4 cases of implementation with initial NPS of 3.

The attribute	Simple order	Order with single tracking number	Order with multiple tracking numbers	Order with GPS tracking
NPS range after implementation	3-4	5-6	5-7	6-9
Reasons for NPS increase	Review of the document without printing	Customer tracks the number at the shipment provider site	Customer tracks several orders independently	The customer sees the geolocation of the parcel at the map in real-time.
ROI, %	105	130	140	178

5 Conclusion

As it is seen from the application of different aspects of presentations for delivery services integration with contemporary web-services rises customer's awareness and trust towards the delivery services use in the applications. The integration of different services and turnover of the client and increase of deliveries positively impact the merchant's rates for delivery calculation.

Costs incurred for implementation indicated that companies with lower cases may still apply cases without GPS and still have a sufficient level of customer satisfaction and keep the net promoters' score at an acceptable level.

Usability approaches create a good level of trust in the commercial applications and their sustainability, especially in case of approach when the service vendor supports returns and keeps the same trustworthy channels of returns creation. This is a logical continuation of the approaches described in many recent publications tied to urban freight surveys [2] and transportation complication indications recently published.

Despite no new environmental methods are proposed – that has been proven that clients trust to green companies, that support closed-loop companies allowing making returns and further recycle retrieved items according to their manufacturing cycle and improvement of logistics that impact the CO₂ emission which is the key point of contemporary publications [3,7].

Developed approach and case study is very easy to use in the real industrial case and validate how the change of the flow positively impacts the customer experience.

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Cost Modeling of Business Processes and Structure of Discrete Accounting Objects: Experience of Restaurant Business

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Abstract. Nowadays, the interest to integrate the concept of business process management with the accounting system and to form accounting and analytical procurement of customer-oriented management is increasing. Customer-oriented management is the priority direction to increase the competitiveness of a restaurant. Its main indicators are maximum customer satisfaction with the menu items, the suitable balance of quality-price ratio, and cutting time of waiting for the order. An innovative discrete approach to the structure of cost accounting objects and business processes is defined. Costing formation by the example of the organism's discrete development in the natural sciences is presented. The concept of customer-oriented management is implemented based on the innovative discrete approach taking into account specifics of the restaurant business. The model of cost accounting of discrete object of a meal "Salad" and the business process of its preparation within time/level of readiness parameters are developed based on system and process approaches. It shows the relationship between time and costs and demonstrates the process of direct costs accumulation of cooking at every stage of the business process. This model will allow us to make well-considered management decisions to improve the restaurant's activity in the future.

Keywords. Costs, Business Processes, Accounting, Restaurant Business.

1 Introduction

The restaurant business in Ukraine has shown rapid growth in recent years. The high level of competition does not allow the use of the price factor to increase revenue. At the same time, customers' requirements for product quality and cutting time of waiting for the order are constantly increasing.

Production costs and time are the main relevant factors of competitive advantage for restaurant businesses in the modern market. However, the real costs of meals and operations in many restaurants are often unclear or give the wrong idea, as the cooking and service processes go beyond the functional boundaries. There are some constraints connected with traditional production cost accounting systems as well.

To gain a competitive advantage, restaurants have to implement innovative

modeling and interdisciplinary methods of structuring discrete accounting objects and transforming business processes. This will transform the cost accounting system and cost calculation.

The purpose of this paper is to describe the experience of a restaurant in a resort town in terms of costs, based on business processes modeling and the structure of discrete accounting objects.

Design / methodology / approach - a case study was performed in the restaurant. Interviews have been conducted and a database of costs and activities have been analyzed.

The scientific hypothesis of the study means that time-based cost modeling of the structure of discrete accounting objects and business processes contributes to the performance improvement of restaurant businesses by identifying and eliminating non-value-added areas.

2 Related works

The social evolution has been influenced by certain factors and phenomena, which have great importance on economic system establishing. The authors presented their views on the civilization process development and created various theories and concepts with the most famous A. Toffler's theory [1]. Accounting, as an integral part of economic affairs, is directly influenced by civilizational transformations. Evolutionary development of accounting took place according to the challenges and requirements of historical periods that followed each other. To describe them, A. Toffler introduced a concept of "waves": agricultural, industrial, post-industrial (information, post-information, digital, knowledge economy).

At the same time, each country and nation have its specifics of civilizational development that influence economic system formation and accounting system transformation. J. Archambault and M. Archambault paid attention to this fact and stated that cultural, social, economic, and political factors can influence the disclosure of financial information [2].

The paper of A. Abeygunasekera, et al. provides a detailed synthesis of the existing literature on the nexus between accounting and BPM. The paper confirms the dearth of work that ties the two disciplines; despite the synergetic multidisciplinary results that can be attained [3].

A comprehensive review of the scientific literature led to the following conclusions. Research that ties BPM and financial accounting was not identified at all. Lack of conceptual work that explores the potential nexus between accounting and BPM, and lack of literature reviews that synthesize prior studies related to aspects of the two areas. Authors encourage accounting researchers to see how they can contribute to another discipline like BPM and encourage BPM researchers to see how well-developed Accounting principles can be applied to address some of the long-standing gaps in the BPM field [3].

They also approved the emergence of publications in the late 1980s and the increase of interest to integrate the concept of business process management with the accounting system since 2007 [3].

Studies of foreign scientists promoted the process approach to management and accounting in Ukraine [4-10]. Business processes in [11-13] are analyzed as accounting and management objects.

3. Cost Accounting System and Business Processes in Restaurants

3.1. Traditional model of cost accounting system

Kherson region has the largest seafront of the Black and Azov Seas in Ukraine. A large number of resort towns and cities set their budgets by tourist infrastructure. Hotels, cafes, and restaurants are densely spaced so they have equal access to the markets for raw materials and labor, delivery channels, and production equipment. The similarity of available food products and a relatively equal level of staff qualifications make it impossible to differentiate the range of restaurant products and individual pricing systems. The competition between restaurants for the most favorable conditions of production and distribution of their products and services is increased by the climate conditions, allowing to work on average four months per calendar year, and the limited number of customers, determined by the places for tourists.

We studied the characteristics of cost accounting and calculation based on the example of the restaurant business of the Kherson region. The analyzed restaurant has the following divisions: (1) Bar, (2) Kitchen, (3) Service, (1) Warehouse.

Let us consider the features of accounting in the kitchen. For accounting in the kitchen is a responsible chef. His duties are not only accounting of raw materials and products, but also controlling the shelf life of products to write it off timely. An important aspect of the restaurant is the minimum price and maximum quality of raw materials for cooking meals and products. Therefore, firstly restaurant considers several suppliers, chooses better terms of supply, and prefers a particular company according to the quality-price ratio of raw materials and regularity/volume of supply. The high competitive level and customer requirements for the quality of products sold by the restaurant require to cook meals from the freshest products.

An important aspect of the restaurant's activity is the menu, which significantly determines its uniqueness and attractiveness to invite more visitors. Menu development is the chef's responsible. The analysis of the menu of several restaurants in Kherson region shows a certain similarity of the assortment, which is usually divided into two parts:

- kitchen menu: breakfasts, cold dishes, appetizers, salads, kinds of pasta, side dishes, pizza, sushi, desserts;
- bar menu: hot drinks, wine menu, cocktail menu.

The next stage of the research is the cost accounting system. In accounting, the costs of food, semi-finished goods, and other products used for cooking ready meals are accumulated on the account "Production". Other costs connected with cooking (salaries of kitchen workers, depreciation of equipment, energy costs) are accumulated on charges account. Each meal or product has its calculation for items of raw materials according to the recipe.

Job order cost card is drawn up for each meal or product which forms costing per a calculation unit based on costs of the raw material and its norms according to a recipe. The restaurant also produces signature dishes sold exclusively in this restaurant with a non-traditional recipe and/or chef's technology. The next step is to specify the value of ingredients per serving, taking into account the output of a particular type of meal or product.

In cost accounting, special attention is paid to the norms of raw materials costs and monitoring their compliance. To meet this goal, the restaurant develops a technological description for each meal (product), which contains the following information: (1) product name and use area of the technological map; (2) list of raw materials to produce the meal; (3) requirements for the quality of raw materials; (4) norms of gross and net weight of raw materials, norms of the output of semi-finished product and finished product; (5) description of cooking technological process.

The percentage of premiums over the purchase price reflects the complexity of the meal and the cost of service. The organization of production is focused on cooking meals based on a certain set of ingredients. The traditional model of the cost accounting system involves the accumulation of direct costs (the cost of ingredients) and price-setting by a fixed trade margin (%).

Consequently, the activity of the restaurant business is connected with different heterogeneous costs neither in composition nor in purpose within cost accounting. In the "as-is" model the first stage is the development of meals from the menu, the second includes calculation and costing, the last stage determines its price. The usage of a fixed trade margin can lead that the price will be much higher than competitors have. As a result, there is a high risk that a particular meal will not be in demand because of the high price and time for order processing. In other words, the traditional model takes into account one of the indicators of customer-oriented management - quality, others - the customer-friendly price and waiting time are not taken into account in the model.

3.2. Modeling of the structure of discrete production cost accounting objects and optimizing business processes

In the previous paragraph, we have analyzed the existing production cost accounting model and identified its drawbacks. Only costs and time can be considered as relevant factors for a highly competitive restaurant business. The price of restaurant products is determined by the market and competitive environment. Therefore, the current economic and industry situation requires using a target price, which will focus on the restaurant. As a result, the pricing formula is changed (Fig. 1).



Fig. 1. Pricing formula with a focus on a target price (author's development)

Thus, the retail price for a meal becomes fixed, costing will consist of the market price of the ingredients, while the trade margin becomes a variable component calculated by dividing the target price and costing. Since cooking technology cannot

be dramatically changed and savings of the products will consequently lead to loss of quality, the problem solving belongs to innovative methods such as business process modeling and the structure of discrete accounting objects.

Business process modeling is prospective, but a relatively new area of accounting compared to other disciplines. It is an interdisciplinary approach to identifying, designing, executing, documenting, measuring, controlling automated, and non-automated business processes to achieve target results according to desired goals.

Cost accounting is a part of management accounting and focuses on the use of financial and non-financial information to plan and control activity and information support of the managerial decision-making process. It refers to identification and accumulation of costs connected with a product, process, or service. Business process modeling is used to improve, redesign, or re-engineer existing business operations to improve overall performance or effectiveness. Accounting and business process management work for the same purpose – to increase business efficiency by identifying productive activities and eliminating unproductive ones.

Let's focus on the kitchen menu. The menu has the "favorite" or "outsider" categories. Favorites include well-known meals with the classic recipe, designed to clients who are not risky enough and have traditional preferences. Meals of "outsider" categories are designed to customers group who prefer to experiment and visit restaurants in search of new exotic flavors, and what is the most important, they are willing to pay a higher price for it. Based on the results of the restaurant visitors interviewing we made the following conclusions: (1) factors such as price, variety, creativity in the recipe and serving meals influence the client's choice; (2) the number of consumers who prefer exotic meals and want to taste something unusual is significantly less than traditional visitors. Based on the presented meals classification, the chef creates a menu of meals that have a classic recipe and signature dishes of a restaurant. Food freshness and the shortest term of cooking are necessary for standard and signature dishes, therefore, it is necessary to form the largest number of dishes with the same raw material base and to optimize the term of cooking. So, the choice of meals and the creation of the menu has a radically different design: the maximum number of meals with a minimum set of products.

Therefore, to design a menu of a restaurant it is necessary to take into consideration that it should contain a various range of meals and ingredients available in the region. Since foods usually have a short shelf life, especially in the summer, the chef should offer a maximum range of different meals with a minimum set of identical ingredients. Another direction is to optimize the process of cooking a meal/product and identify items that will shorten the cooking time. Accordingly, a discrete structure of finished goods (meal, product, etc.) and a business process reflecting the flow of cost formation in stages become the objects of the cost accounting system.

3.3. The architecture of an innovative cost accounting model and results of the implementation

Gotze and Mikus [14] identify three directions of management to improve performance efficiency: to improve product quality, to reduce service time, and reduce product unit cost. Each theory becomes more clear and available if it can be

applied to solve practical problems. We will present the analysis and synthesis of discrete accounting objects (a meal and its cooking process) in restaurants. We will use elements of combinatorics and build a model of cost accounting of production and costing of a meal within customer-oriented management on the example of Caesar salad by classic recipe.

A meal “Caesar salad” according to the classic recipe consists of a certain set of ingredients. Firstly, we combine certain ingredients into components such as salad mix, dressing, and other ingredients. The salad mix contains a set of standard greens. In this approach, the salad mix (basil, dill, parsley, green onion, another salading, etc.) should become the first component of a subgroup of salad groups.

The second component will be dressing. Each salad has its dressing, but the set of ingredients is almost identical except for the single spices that determine the individual taste. The third component is a set of standard salad products (eggs, cheese, etc.). The allotted time for cooking any salad from the restaurant menu is 30 minutes. The pace of life of modern people is very fast, so the time of salad cooking should be reduced. Another reason is to free up time for a customer to order an extra meal, even if he has not planned it. Let’s consider the model of cost accounting and costing in time/availability parameters (Fig. 2).

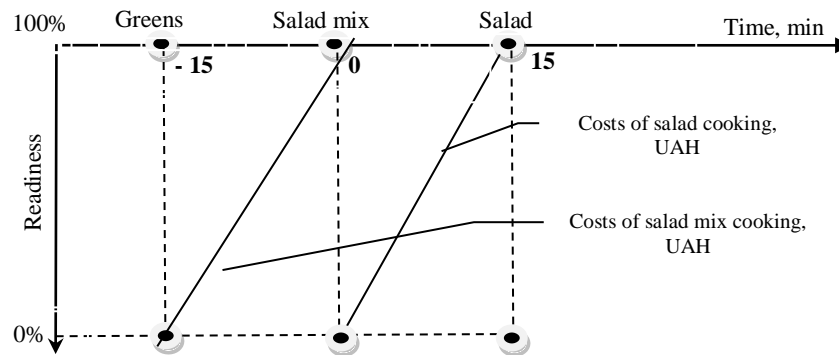


Fig. 2. Model of the discrete cost accounting object of a “Salad” and business process of its cooking in time/level of readiness parameters

It should be noted that the perception of the model will be different from the observer’s status. The observer in the internal system (restaurant) will see two separate processes of cooking, and therefore the costing formation. The first stage is the cooking of a salad mix from a set of standard greens. If it is ready, in the accounting system the salad mix will be entered in records as an own produced semi-good. During the salad cooking process “Salad mix” is displayed as one of the components of the meal. Whereas, the salad, as an object of accounting for production, begins to accumulate costs from scratch.

Time as a category is equal to pronounced 30 minutes with a gap in the middle of the timeline, which allows preparing the mix in advance before the order is received from the restaurant hall. For the observer from the external system, in our case, the client, salad is perceived as the one object with the cooking time in 15 minutes.

Let’s introduce the implementation of the proposed model in the software environment (Fig. 3). To reflect the costs of cooking in the model, it is necessary to

create a base of ingredients in the program to form the costing of the modifiers and the meals. In an item master data a group of "Semi-finished goods" is formed, which will include components of future meals. All other ingredients for cooking are included in the group "Raw materials for the kitchen".

Caesar salad

Гр	Код	Наименование	Ед.изм	Точ.вес	Замена	Закупка	Розница	Закупка, за 1 кг	%Нац	Розница, за 1 кг	Брутто	Нетто	Выход	Закупка	Розница
30	910	Заправка цезарь	порц	1		12,24	22,03	12,24	80	22,03	1	1	1	12,24	22,03
30	912	САЛАТНЫЙ МИКС	порц	1		4,98	8,96	4,98	80	8,96	1	1	1	4,98	8,96
02	149	Сыр Пармезан	кг	1		330	594	330	80	594	0,02	0,02	0,02	6,6	11,88
02	116	Помидор в асс	кг	1		10	18	10	80	18	0,07	0,07	0,07	0,7	1,26
02	164	Хлеб	шт	1		10,4	18,72	10,4	80	18,72	0,02	0,02	0,02	0,21	0,37
Итого по калькуляции:											2,110	2,110	2,110	24,730	44,508

Dressing Caesar Salad mix

Fig. 3. The job order cost card "Caesar salad with chicken"

The item master data will record as well the name of finished goods: meals, drinks and others, so it is intended to form a full list of products used in the restaurant in the database. The use of the item master data allows accruing a trading margin on the purchase price of raw materials.

The costing writing off the process of a sold meal is done in an algorithm. The first step is to receive an order from a customer. The waiter accepts the order from the guest, puts it in the monobloc, then the order goes to the kitchen through the printer. The program already contains information about the structure of the meal in the job order cost card. The costing of the meal is written off the costs simultaneously with the revenue reflecting from sales at the time of recording the order. If information is recorded timely and correct, data on the value of sold products and residue stock in the kitchen will be the most accurate and available online.

4 Conclusions and Suggestions

The traditional cost accounting system and costing of meals of the restaurant are based on the direct costs of production while costing of self-made meals/products is determined by the prices of raw materials and purchased semi-finished goods and retail margin. Other costs are considered indirect. The retail price of a meal is based on costing and a fixed margin expressed as a percentage. As our restaurant is not a VAT taxpayer, it is not included in the calculation. The traditional model of cost accounting means the accumulation of direct costs (product costs), which determine the cost of a meal, and the formation of prices by a fixed trade margin (%). However, the methodology does not take into account indicators of customer-oriented management.

The obtained results confirm the scientific hypothesis and allow us to formulate the following conclusions: to gain competitive advantages aimed at maintaining a

positive image of the restaurant, we proposed innovative transformations for the maximum customer satisfaction within the shortest possible period of time. To implement the innovation, an innovative structured approach for the cost accounting model was developed: (1) modeling the structure of discrete accounting objects, the business process optimization, and establishing the interrelation of the structural elements of the accounting objects and stages of the business process with the time factor; (2) the architecture of an automated cost accounting system based on financial accounting data to implement innovation and automated software development.

The proposed innovative approach was implemented in the restaurant and has created specific economic benefits. A new understanding of accounting (discretion) and technological process (business process) is the result of research that qualitatively differs from its previous comparables, creates new consumer values, and promotes a positive image of the restaurant and economic impact. The use of a target price for a meal/product radically changes the pricing method, namely, the retail price becomes fixed and is set according to the market situation and the price of competitors. The trade margin becomes a variable indicator calculated by dividing the target price and costing, which allows managing the relevant factors.

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Risks of the methodology for forecasting the price of bitcoin and the frequency of its online requests in the digitalization of economic systems

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Abstract. *Research goals and objectives:* to study the series of dynamics of the frequency of requests and the price of bitcoin under the conditions of taking into account the risks of using various forecasting methods.

Subject of research: proof of importance of the role, statistical dependence and interdependence of the series of dynamics of the price of bitcoin and the frequency of its online requests.

Research methods used: analytical methods, econometric models, nonlinear dynamics methods.

Results of the research: The research grounded the approach and the forecasting procedure for the series of dynamics of the price of bitcoin and the frequency of its online requests, which in essence correspond to the basic principles of the implementation of the forecasting methodology, take into account the specifics of the formation of the frequency of online requests for bitcoin prices and the socio-economic meaning of its functioning. The practical value consists in determining that the minimum risks for the study of a time series dynamics of bitcoin price and frequency of requests for bitcoin price were demonstrated by the neural network methodology in comparison with the use of the ARIMA model and other methods of economic and mathematical modeling that proves the proposed methodology for determining the direction of the trend outside the study period.

Keywords. bitcoin price, frequency of requests, time series of dynamics, forecasting, risks, methodology, neural networks, ARIMA models.

1 Introduction

The cryptocurrency phenomenon has proved the promise of the search for alternative exchange units, whose circulating capabilities will not be limited by state money supply regulation mechanisms and exchange rate policies of national banks, and, in

general, will operate according to the principles of decentralization in the online environment. Only market conditions in their pure form make it possible to reliably assess the investment attractiveness and financial prospects of new instruments, the functioning space of which are not limited to the real market, but cover the online environment. This is completely logical, since bitcoin is a product of cryptography, the development of digital technologies, and the spread of their use in economic systems.

The atypical and contradictory nature of bitcoin requires a thorough study of its parameters and features of functional development in a real socio-economic environment of practitioners and scientists who still have not come to a final thought about the benefits and the risks that accompany them [1]. The cryptocurrency decentralization mechanism, which is manifested in the confidentiality and unrestrictedness of purchases and sales, includes all the same elements of centralized functioning due to the involvement of intermediaries in the mechanism. Intermediaries, in particular, for the provision of digital wallet services, Mixers, Mining Pools and others, which together provide minimization of constant costs, expand the capabilities of users and etcetera, but also have a cost and additional risks [2]. Over time, the complexity of the functional mechanism of cryptocurrencies only increases, so the systemic and non-systemic risks change, form a new list of threats. However, interest in cryptocurrencies is not waning.

Thus, the growing attention of the world community to the digitalization of socio-economic processes is a prerequisite for the emergence of a new alternative exchange currency – cryptocurrency. Their gradually increasing availability in the markets, despite the attendant risks, has formulated a steady demand for cryptocurrency for both the object of investment and exchange. Therefore, the mechanism of functioning of the cryptocurrency and curative differences require a systematic monitoring of key parameters, which is easiest and fastest to do in an online environment.

Now, sufficient technical attention to cryptocurrency has supplemented with economic content and outlined the circle of social issues that arose in the formation of the cryptocurrency market. In general, Marella V., Lindman J., Rossi M., and Tuunainen V. consider that “Bitcoin is a social movement in the financial industry” [3]. As a result, despite the insufficient level of awareness, technical and financial literacy of the population of developing countries, and thanks to the principle of decentralization, the dynamics of interest in cryptocurrencies in the online environment, in particular, bitcoin, are changing in accordance with changes in trends in their exchange rate, which is currently little studied.

The purpose of the paper is to study the time series of dynamics of the frequency of requests for bitcoin, taking into account the risk of using various forecasting methods. The object of the research is the time series of the frequency of requests for bitcoin in Ukraine according to Google Trends and bitcoin price. The subject of the research is the risks of forecasting series of dynamics.

2 Related Work

The dynamic series of cryptocurrencies are investigated by a wide range of methods, which today has formed a certain knowledge base of their accuracy, adequacy and appropriateness of application. But, given the constant updating of statistical data, the search for an adequate methodology for forecasting cryptocurrency parameters will be relevant and timely at every stage of development.

Today, the results of researches of the bitcoin price time series dynamics in the context of explaining the laws of its changes by the situation of modern economic theories have proved their practical value; also, the activity and behavior of market agents in general were taken into account, in particular, the influence of social networks and the structure of the formed cryptocurrency market, which is constantly evolving, was noted and is being improved [5]. The methods of machine learning and modeling are actively used to forecast the trajectory of changes in the parameters of bitcoin (most often, the dynamics of the price) and the cryptocurrency market [4, 5]. In particular, there are results of using:

- linear models [8], but non-linearity is inherent in socio-economic processes, which limits the possibility of applying the approach;
- nonlinear autoregression [9], where the accuracy and quality of approaches is limited when applied to data such as random walk;
- binomial logistic regression [10], the implementation of a Bayesian optimized recurrent neural network, Long Short Term Memory network and the ARIMA model [6], effect of Bayesian neural networks [7], where from the practice of using approaches it is proved that in the accuracy of forecasts ARIMA models are significantly inferior to the results of using neural networks;
- methods of the theory of complex systems have been successfully used to justify the forerunners of critical changes in the bitcoin exchange rate [11], but qualitative results were obtained on the trend in 2017 and it is not known what results will be for the updated trend of the input data and whether the technology can determine the direction of the trend.

Separately, note that a connection has already been established between bitcoins and search information in Google, Wikipedia materials about them in an online environment [12]. In addition, researches of the interdependence of requests in social networks and the bitcoin exchange rate [13] are valuable, where a positive effect of the growth of its popularity on the growth of search queries was established. In the article [14], the authors studied the self-similarity and multifractal features of the bitcoin exchange rate series, which corresponds to the nature and degree of complexity of the bitcoin ecosystem. Also, the authors of [14] proved the feasibility of taking into account indicators of social networks in order to predict the exchange rate of bitcoin using fractal analysis methods.

The results of forecasting accuracy and the adequacy of forecasting models differ methods at different periods of bitcoin course research, but scientists focus mainly on machine learning methods. However, today the social aspect of the cryptocurrency

market is actively being studied, the quantitative and qualitative impact of this phenomenon on various areas of socio-economic existence.

3 Risk

Forecasting as a methodology is constantly tested for adequacy to the realities of socio-economic processes, since their complexity and unpredictability only increase over time. The emergence of new tools requires taking into account not only the results of the analysis of the series of dynamics that they produce, their economic meaning, but also against the background of taking into account the risks of functioning of the research object itself, the risks of using the chosen forecasting methodology.

Thus, the risk structure is presented as a set of risks directly using the forecasting methodology, and a set of risks that are inherent in the bitcoin functioning system (forming a circle of relevant interests of online market agents), namely: internal and external (technological, social, economic, interest in security, political and so on):

$$R = \langle R^S, R^M, t \rangle, \quad (1)$$

where $R^S = \{r_i^S\}$ – the set of systemic risks inherent in the price of bitcoin (the frequency of requests for bitcoin), which are allocated from the socio-economic environment for the period t ;

$R^M = \{r_j^M\}$ – the set of methodological risks of forecasting for the period t .

The list of risks of the forecasting methodology includes such factors as: the probability of making a mistake in choosing formal-informal methods and models; the probability of achieving the goal of the study; the reliability of the results; accuracy of their interpretation; excessive subjectivity in prediction; reassessment of the capabilities of the resulting models; quality and reliability of information support and etcetera. Most of these risks relate to the subjective and organizational aspects, therefore, their level directly depends on the subject who makes the decision and the availability of methodological tools, the measure of their mastery, reliable initial data for the required period. Prediction as a phased process forms the level of aggregate risk with a cumulative total, therefore its final value is determined by the product of risk indicators of each stage of its implementation. Significant of taking into account methodological risks involve that the prognostic results are based on entities making financial and investment decisions, which together form the behavior and set the cryptocurrency spread rates, the unregulatedness of which also forms a circle of risks for users. Therefore, the issue of choosing a forecasting methodology is given special attention.

4 Method

The forecasting methodology should include the use of several methods to develop a forecast and select the best of them based on estimates of the accuracy and quality of the forecast. Thus, the authors proposed a methodology for predicting the price of bitcoin and the frequency of online requests for bitcoin, which consists of four interrelated steps (fig. 1).

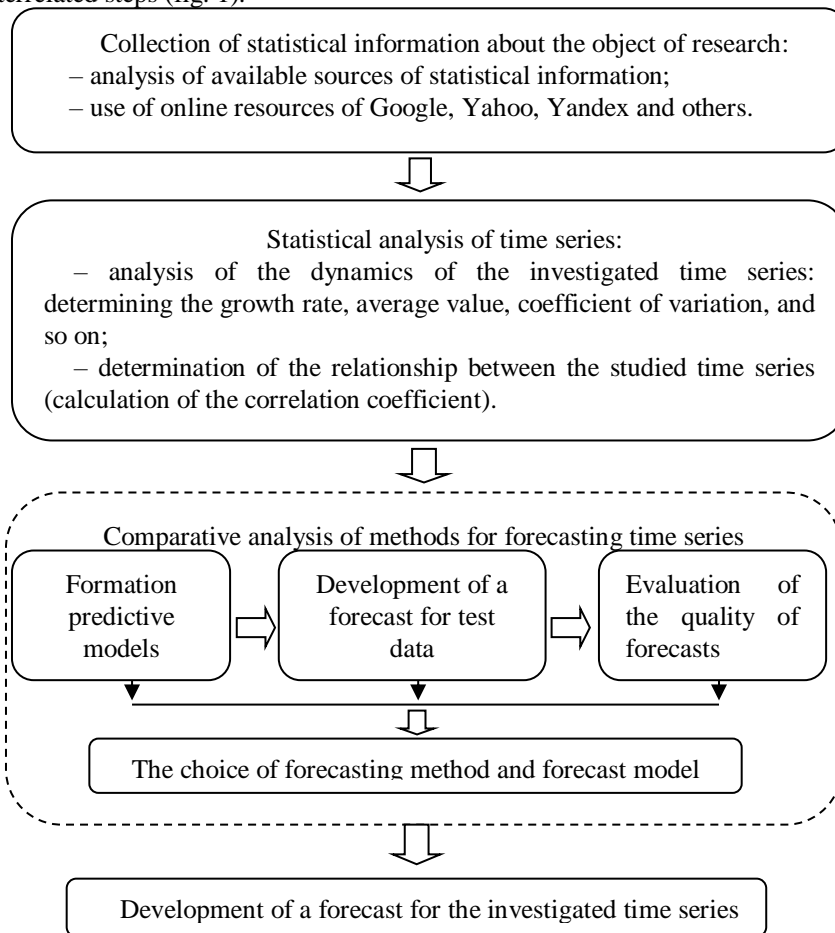


Fig. 1. Methodology of time series forecasting

The set of initial statistics consists of two time series, namely: the frequency of online requests for bitcoin in Ukraine and the price of bitcoin. Time series were generated using data from Google Trends [15] and InvestFunds [16] for the period from January 18, 2015 to January 12, 2020.

Statistical analysis of the studied time series will reveal the maximum, minimum and average values of the series, as well as establish the growth rate, measure the

variability of the series and measure the relationship between the studied series. If necessary, standardizing of time series is carried out.

Further, in accordance with fig. 1, forecast models are directly developed. To study the series of dynamics, the authors selected several approaches to forecasting (econometric models and non-linear dynamics methods), among which the best results were shown by neural networks and ARIMA models. Thus Auto-Regressive Integrated Moving Average (ARIMA) model and Neural Network Auto-Regressive (NNAR) model were chosen.

The Auto-Regressive Integrated Moving Average (ARIMA) model describes the time series by two main processes, namely: the process of autoregression and moving average. Most time series contain elements that are sequentially dependent on each other. This dependence can be expressed by the equation:

$$x_t = \delta + \beta_1 \cdot x_{(t-1)} + \beta_2 \cdot x_{(t-2)} + \beta_3 \cdot x_{(t-3)} + \dots + \varepsilon_t, \quad (2)$$

where δ – constant;

$\beta_1, \beta_2, \beta_3$ – autoregressive parameters;

ε – random component.

Thus, each observation is the sum of a random component and a linear combination of previous observations. The autoregression process will be stationary only when its parameters are in a certain range. For example, if there is only one parameter, then it must be in the range $-1 < \beta < +1$. In the opposite case, the previous values will accumulate and the values of the next x_t can be unlimited, respectively, the time series will not be stationary.

Unlike the autoregression process, in the moving average process, each element of the series falls under the combined influence of previous errors. In general terms, this can be represented as follows:

$$x_t = \mu + \alpha_1 \cdot x_{(t-1)} + \alpha_2 \cdot x_{(t-2)} + \alpha_3 \cdot x_{(t-3)} + \dots + \varepsilon_t, \quad (3)$$

where μ – constant;

$\alpha_1, \alpha_2, \alpha_3$ – moving average parameters;

ε – random component.

That is, the current observation of a time series is the sum of a random component at a given point in time and a linear combination of random influences at previous points in time. It should be noted that between the processes of the moving average and autoregression there is “duality” – one equation can be rewritten in the form of another and vice versa (reversibility property). Similar to the stationary conditions, there are conditions that ensure the reversibility of the model.

The generalized ARIMA model includes both autoregressive parameters and moving average parameters. The model is described using three parameters: autoregressive parameters (p), difference order (d) and moving average parameters (q). This model is described as follows: ARIMA (p, d, q).

The next forecasting method is the Neural Network Auto-Regressive (NNAR) model. Artificial neural networks allow to explore complex non-linear relationships between incoming and outgoing variables. They are widely used for approximating functions and forecasting. The main advantage of these models is that they allow the approximation of a large class of functions with a high level of accuracy. In this model, older values of the time series are used as input data of the model, and forecast values are used as outgoing values. The NNAR model can be represented as a neural network, which includes a linear combination function and an activation function [17, 18, 19]. The linear combination function can be given in the following form:

$$net_j = \sum_i w_{ij} x_{ij} . \quad (4)$$

The activation function is a sigmoid function and is defined as follows:

$$f(x) = \frac{1}{1 + \exp^{-x}} . \quad (5)$$

The network inputs are connected using a linear function and, as a result of various combinations, are then transmitted through a sigmoid nonlinear activation function. In accordance with the article [20], the weights of the neural network are updated using the inverse propagation algorithm. Weights in the neural network are selected so that the forecast error is minimal.

This article uses the following model designation: NNAR (p, k), where the first parameter (p) shows the number of lags and the second (k) – the number of nodes in the hidden layer.

Having built forecast models ARIMA and NNAR, they should be verified and the quality and accuracy of the forecast should be determined. As estimates of the accuracy of the forecast, mean absolute percentage error (MAPE) is used, which is determined by the following formula:

$$MAPE = \frac{100}{\tau} \sum_{t=T+1}^{T+\tau} \left| \frac{x_t - \hat{x}_t}{x_t} \right| . \quad (5)$$

As a result of model verification, the model that has the minimum forecast error is selected [21].

5 Results

The forecasting methodology proposed by the authors was tested for two time series: the price of bitcoin and the frequency of requests for bitcoin of Ukrainian online users in Google Trends. The initial data are weekly values, and the observation base was 261 periods. Thus, the regulatory independence of Bitcoin has led to a close relationship between its price and demand, which proves the similarity of the series of

request frequency and bitcoin price in fig. 2. The circle of interests in cryptocurrencies in the online environment is characterized by the structure of the semantic core of requests from market agents, the frequency of which in different periods determines the direction of their changes, which is explained by the socio-economic factors of influence of the studied period. Consequently, the level of interest in the object and the frequency of its online queries is characterized by a direct proportion. The most popular structure of the semantic core is the simplest semantic unit, therefore it has a significant number of semantic links and corresponds directly to the name of the electronic currency - "bitcoin". The relationship of more complex requests with the core "bitcoin" has not been investigated.

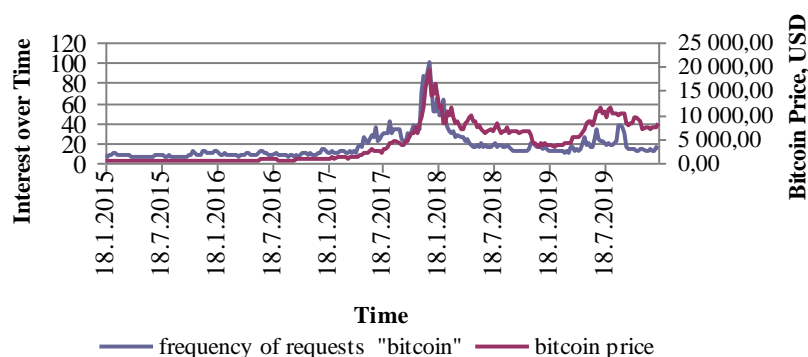


Fig.2. The time series of dynamics of the price of bitcoin and the frequency of online requests "bitcoin" according to Google Trends in Ukraine

In accordance with the data in fig. 2, as we can see the price of bitcoin is quite volatile. So, on August 06, 2012, its maximum value is traced at the level of 3,213.94 USD, and on January 18, 2015, the minimum value is recorded – 210.34 USD. It was found that for the study period, the price of bitcoin increased weekly by an average of 2%, and the frequency of requests - by 2.1%. The maximum increase in bitcoin value is 41.5% (July 23, 2017), the minimum increase is 29.8% (April 02, 2018), and the average price of bitcoin was 4023.752 USD. In the studied time series of the price of bitcoin, there is a high variability of values, as evidenced by the coefficient of variation, which is 91%.

It was during the period when the bitcoin price reached its maximum that the frequency of requests in the online environment for the keyword "bitcoin" also reached its maximum value - 100 interest over time. At the same time, the minimum value of the number of bitcoin price request frequency rates (5 interest over time) was observed in several periods: April 19, 2015, May 17, 2015, June 06, 2015, June 14, 2015, September 06, 2015, September 13, 2015, April 10, 2015, November 10, 2015. These dates correspond to the period when the bitcoin price dynamics is characterized by a low level of volatility. For the analyzed period, it was found that on average there were 17 interest over time per week. Thus, it can be argued that the interest in

bitcoin in the online environment increases and forms a number of dynamics similar to the dynamics of its value in periods of significant fluctuations. The stability of its exchange rate does not arouse the interest of market agents, therefore, they conduct certain periodic monitoring.

The correlation coefficient between the studied series of dynamics (fig. 2) is 0,73, which proves the tightness of the relationship and the interdependence of their trends. A more pronounced similarity of trends is observed during periods when the Bitcoin exchange rate was characterized by significant volatility. Consequently, the variability of exchange rate fluctuations, among other factors, causes an increase in interest from market agents, which is expressed by a corresponding change in the frequency of their requests in the online environment. The weight of the research of the influence of the dynamics of the frequency of requests “bitcoin” is explained by the fact that this semantic core with a significant level of popularity in the online environment determines the behavior of market agents. In addition, the frequency of the indicator may form an idea of the possible demand for cryptocurrency.

The indicated sensitivity of the frequency of online requests to exchange rate fluctuations of bitcoin is more pronounced than in other currencies, in particular, between the exchange rates of the euro, the dollar and the frequency of their online requests (fig. 3).

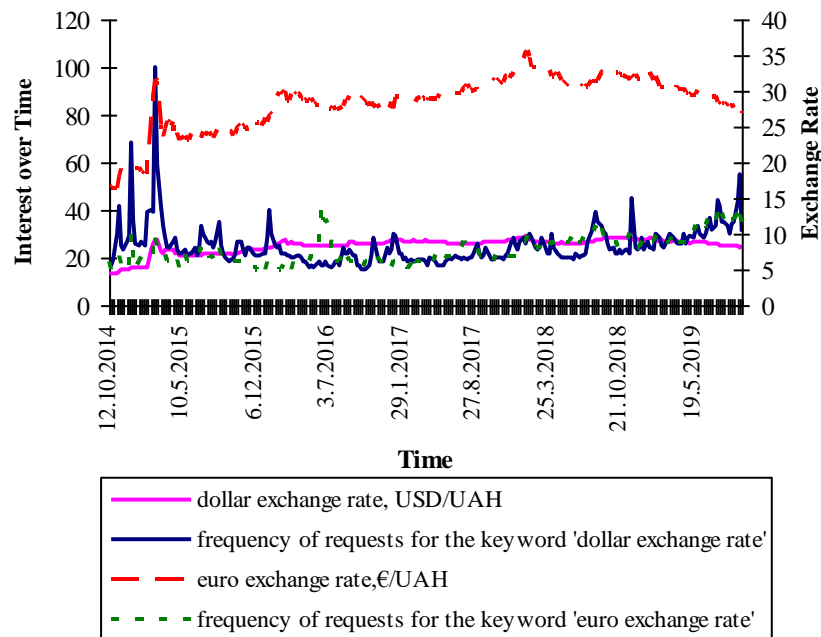


Fig. 3. The time series of dynamics of the exchange rates and the frequency of online requests "dollar" and "euro" according to Google Trends in Ukraine

The aforementioned is explained by the limiting influence of the monetary policy of the states and the International Monetary Fund, therefore, the connection density is present, but not significant ($k = 0.37$). And this is logical, since at the given moment all states are trying to limit the possibility of the outflow of the national currency from the country by means of cryptocurrencies and technologies [22; 23].

In accordance with the proposed methodology (fig. 1), the next step is to build models for predicting the studied time series, namely, the price of bitcoin and the frequency of requests. To build the models, used the tools of the R environment, namely the "forecast" library. The time series was divided into training and test sets. The training set was 96% of the data (251 values, data from January 18, 2015 to November 03, 2019), and the test set was 4% of data (10 values, from November 10, 2019 to January 12, 2020).

By analyzing the data in fig. 2, we can state that there are peaks and drops in the trend direction in the time series. The investigated time series are non-stationary, which confirms the advanced Dickey-Fuller Test. On the other hand, with a fairly high level of confidence, it can be argued that the first-order differences of the series are stationary, that is, these are integrated first-order time series. There is no seasonal component in the time series, but a random component is present. In the medium term, compared the predictive models of ARIMA and the neural network.

In fig. 4 and fig. 5 shows the constructed predictive models for the test set of the time series – the price of bitcoin.

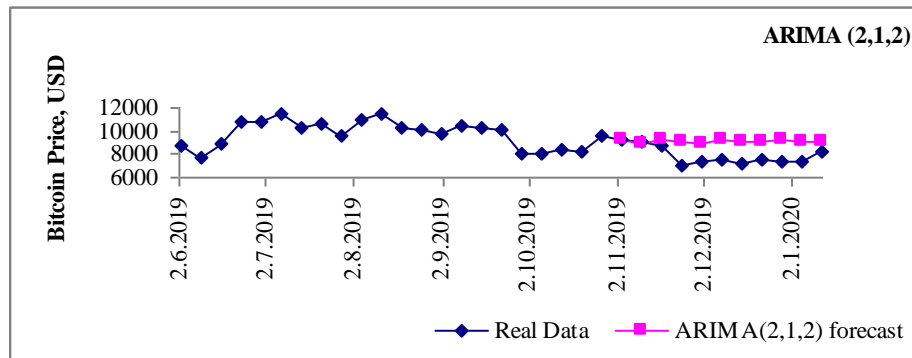


Fig. 4. Forecast from ARIMA (2, 1, 2) for the test set the price of bitcoin

Thus, the constructed ARIMA model (2,1,2) contains two autoregressive parameters and two moving average parameters, which are calculated for a time series after taking the difference with lag 1. Also, the authors obtained the NNAR neural network (7, 7), in which the length of the lag and the number of nodes in the hidden layer are 7.

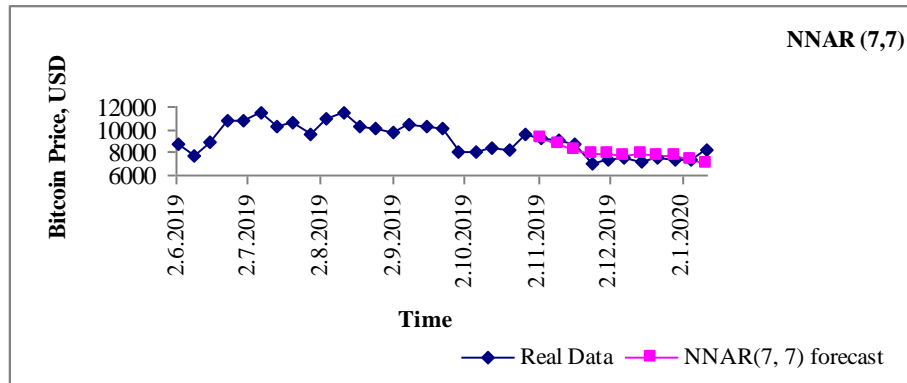


Fig. 5. Forecast from NNAR (7, 7) for the test set the price of bitcoin

Compared the obtained predicted values for the constructed models with real data in the test set. From the graphical representation of the data in fig. 4 and fig. 5 shows that the predicted data of the NNAR model (7, 7) are closer to real ones. From fig. 6 as we can see the obtained forecast data do not go beyond the 95% confidence interval, that is, there is a fairly accurate forecast. This is also evidenced by the value of the mean absolute percentage error (MAPE): for ARIMA it is 18.4%, and for the neural network – 6.1%. Therefore, for medium-term forecasting of the price of bitcoin, it is better to use a neural network NNAR (7, 7), since the forecast will be more accurate.

The results of forecasting the price of bitcoin for the next 10 weeks (January 19, 2020 – March 22, 2020) using the model NNAR (7,7) are presented in fig. 7. In accordance with the forecast, the price of bitcoin in this period will have a decreasing trend and decrease by 25, 6%, from 8192.49 USD to 6093.467 USD per bitcoin.

For the time series of the "bitcoin" request frequency from Ukrainian online users the best ARIMA model for test data was ARIMA (0, 1, 0). And the best neural model for the time series of requests for bitcoin is the NNAR (8,7) (fig. 8). Comparing the predicted values for the obtained models with real data in the test sample (fig. 9), we see that they do not go beyond the 95% confidence interval.

The mean absolute percentage error (MAPE) value for the ARIMA model is 9.09%, and for the neural network – 11.7% (table 1). But it should be noted that the ARIMA model (0,1,0) is a random walk model, so the forecast can be made only one period ahead. Therefore, this model can only be used for short-term forecasting. For medium-term forecasting of requests for bitcoin of Ukrainian online users, a neural network model was used, namely, NNAR (8, 7).

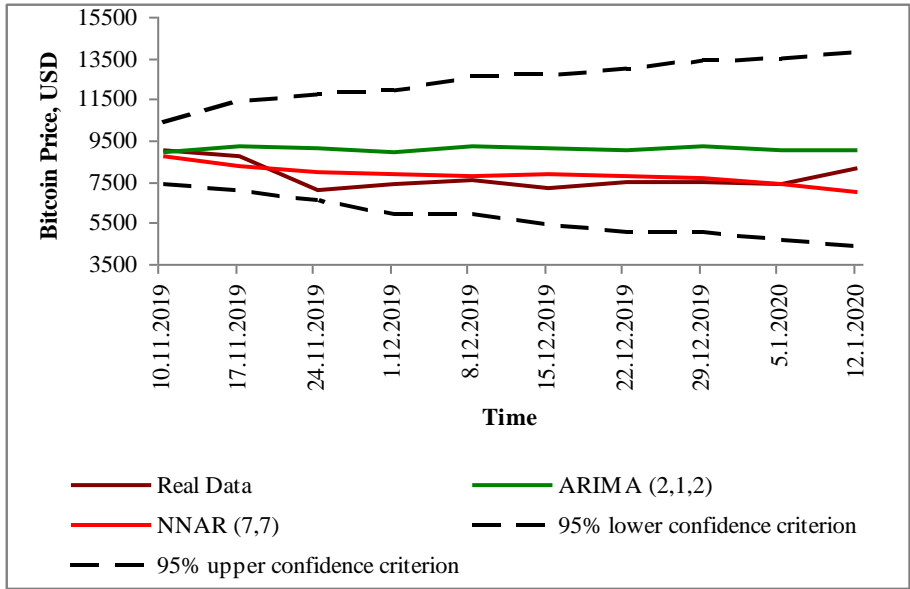


Fig. 6. Forecast for the test set the price of bitcoin



Fig. 7. Forecast from NNAR (7, 7) for the price of bitcoin

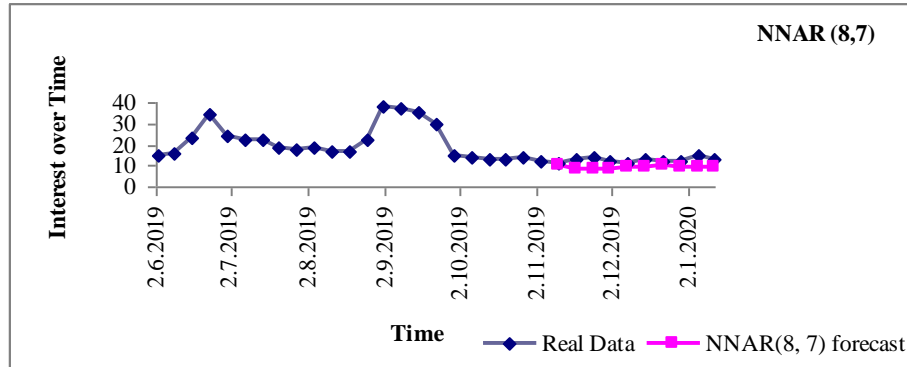


Fig. 8. Forecast from NNAR (8, 7) for the test set the requests "bitcoin"

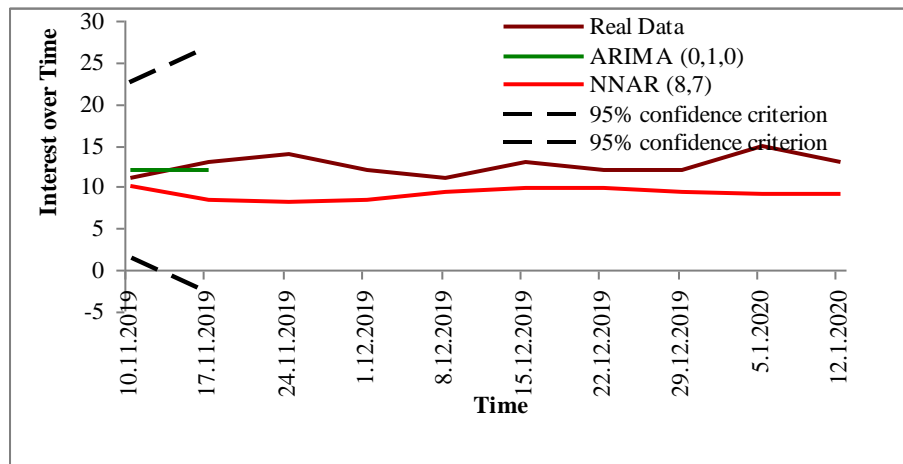


Fig. 9. Forecast for the test set the requests "bitcoin"

Table 1. Comparing forecasting results

Time	Auto-Regressive Integrated Moving Average (ARIMA) model		Neural Network Auto-Regressive (NNAR) model	
	the price of bitcoin	the frequency of requests for bitcoin	the price of bitcoin	the frequency of requests for bitcoin
10.11.2019	8878,67	12	8721,588	10,134
17.11.2019	9227,636	12	8211,657	8,497
24.11.2019	9148,794	12	7962,576	8,135
01.12.2019	8943,138	12	7876,07	8,370
08.12.2019	9230,276	12	7733,796	9,366
15.12.2019	9092,271	12	7823,07	9,749
22.12.2019	9001,815	12	7781,075	9,816
29.12.2019	9214,146	12	7628,991	9,478
05.01.2020	9060,785	12	7344,58	9,218
12.01.2020	9049,155	12	7016,984	9,249

MAPE	18,4%	9,09%	6,1%	11,7%
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The results of forecasting the frequency of requests "bitcoin" by Ukrainian online users for the next 10 weeks (January 19, 2020 - March 22, 2020) are presented in table 2.

According to the forecast, the frequency of requests "bitcoin" of Ukrainian online users in this period will increase by 41.7%, from 12 interest over time to 17 interest over time per week. Thus, it is forecasted that the average frequency of requests will increase by 2.4% weekly.

Table 2. The forecast of the studied indicators by the method NNAR

Time	The price of bitcoin		The frequency of requests for bitcoin	
	\$USD	Rate of increase, %	Request frequency	Rate of increase, %
19.01.2020	7627,617	–	13,83168	–
26.01.2020	7421,916	-2,70%	14,71267	6,37%
02.02.2020	7058,429	-4,90%	14,03004	-4,64%
09.02.2020	6631,057	-6,05%	15,26786	8,82%
16.02.2020	6556,085	-1,13%	16,18115	5,98%
23.02.2020	6238,652	-4,84%	15,41361	-4,74%
01.03.2020	6267,147	0,46%	15,93974	3,41%
08.03.2020	6252,667	-0,23%	16,31639	2,36%
15.03.2020	6123,963	-2,06%	16,42473	0,66%
22.03.2020	6093,467	-0,50%	17,04905	3,80%

6 Conclusions

As a result of the research, the importance of taking into account the risks of the methodology for predicting the key parameters of bitcoin, whose nature and mechanism of functioning are distinguished by decentralization, self-organization and the internal complexity of processes increasing in time, is confirmed. The indicated characteristics of an electronic instrument today have shown a limited methodology and variability in the risks of using various methods of forecasting and predicting both the price of bitcoin and the frequency of requests "bitcoin". The studied series of dynamics are defined as integrated time series of the first order, non-stationary, with no seasonal, but with a random component present, which corresponds to the features of the mechanism of functioning of bitcoin. The statistical dependence and interdependence of the series of the dynamics of the price of bitcoin and the frequency of online requests for bitcoin is proved. Interest in bitcoin in the online environment is growing like the dynamics of its course during periods of significant volatility. Whereas during the period of stabilization of the price of bitcoin, uniform periodic monitoring is carried out in the online environment. Certain patterns can be used to explain the trends in bitcoin parameters and the socio-economic behavior of agents in this market sector. The article defines the approach and forecasting procedure for the studied series of dynamics, which essentially correspond to the basic principles of the forecasting methodology and takes into account the specifics

and socio-economic content of the price of bitcoin and the frequency of online requests about it. Based on the results of applying forecasting methods to the studied time series of dynamics, it was determined that the processes of self-organization of the bitcoin functioning mechanism provide for the advisability of using forecasting methods with internal procedures for self-learning, self-tuning and adaptation in real time. So, the minimum risks for the study of the bitcoin price time series dynamics were demonstrated by the neural network methodology in comparison with the use of the ARIMA model. Although estimates of forecasting quality using the methods used are generally acceptable, the risk of using the ARIMA model methodology also lies in the fact that its advisability can be limited only to short-term forecasting (for one period), while neural network technology justifies itself in medium-term forecasting tasks. Given the dynamism and daily updating of data on the parameters of bitcoin, in practice it most often manifests itself in short-term forecasting, while for basic research is - medium and long-term forecasting. The authors also note that the results of forecasting the price of bitcoin for the period January 19, 2020 - March 22, 2020 prove the formation of a decreasing trend (-25.6%), while the forecast frequency of requests during this period will increase by 41.7%. Since the authors have proved that an increase in the frequency of requests "bitcoin" corresponds to its high volatility in the direction of increase, it is logical to say that in the forecast period, the dynamics of the price of bitcoin will be characterized by high variability and an increase will take place after a certain decline. Subsequent researchers provide for a recurrency analysis of bitcoin prices and the frequency of online requests "bitcoin", which will complement knowledge about the risks of using separate methodologies for their forecasting, evaluation, and analysis.

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Deep Learning Forecasts of the Electricity Price with special Consideration of the Electricity Supply

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Abstract. The market price for electricity at the energy exchange is mainly determined by supply and demand. For many market participants, electricity price forecasting is an important competitive factor. Previous research primarily predicted based on demand. In times of renewable energies this mantra is no longer sustainable. This study primarily looks at the supply-side prediction of the electricity price with the help of deep learning artificial neural networks and thus makes a contribution to the literature. Autoregressive models and regressions serve as benchmarks.

Keywords: electricity price forecasting, ARIMAX, regression, artificial neural networks, deep learning

1 Introduction

Due to the global increase in population and the rise in the general standard of living, a reduction in electricity demand is not foreseeable [2]. Fossil fuels continue to be the foundation of the global energy supply: coal, natural gas and crude oil. Worldwide, renewable energies such as hydropower and biomass contribute around 18% to covering electricity demand [35].

With about 70% of imported raw materials, Germany is one of the largest energy consumers worldwide. For this reason, the German government's goal is to increase the share of renewable energies in primary energy consumption from 14% (as of 2018) to 40-45% by 2025 [3]. Despite this, coal and nuclear energy have been very important energy sources for decades, even though their share in electricity generation has fallen from 84% in 1990 to currently less than 50% [33].

On the European electricity exchange (EEX), the price for electricity is determined by supply and demand. It should be noted that this is only a peak balancing, as most participants in the electricity market cover themselves by means of long-term electricity supply contracts with the power plant operators. Only short-term peaks are balanced via the electricity exchange.

It is essential for market participants in the electricity market to be able to make substantive statements about future electricity price developments. Above all producers and traders can gain great competitive advantages through accurate electricity price forecasts.

In the past, electricity supply largely followed demand. In order to ensure network stability, the amount of electricity fed into the grid must always be adapted to demand. This is ensured by using peak load power plants, such as gas turbine power plants. The latter produce comparatively expensive electricity compared to base load power plants such as coal-fired and nuclear power plants. These types of power plants can be adapted very quickly

to fluctuating electricity demand, whereas base-load power plants have a very high time latency. Due to the increasing use of renewable energies, such as wind and solar power, and the resulting displacement of base-load power plants, the problem of maintaining grid stability remains, but the electricity mix is constantly changing and with it the electricity price. The final consequence of this is that the supply of electricity can no longer be fully derived from the demand for electricity, and consequently the supply of electricity is a factor influencing the price of electricity. However, the latter is still not independent of the demand for electricity, so that collinearities and endogeneities arise.

The forecast of the electricity price has also been a relevant topic in the literature for many years. In this respect, a large number of authors have taken up this challenge. However, the focus of most studies is on the demand side of electricity price forecasting. A recent research has detected 105 papers that are dedicated to a demand-side electricity price forecast. In contrast, 11 papers (see **Error! Reference source not found.**) clearly underrepresented the supply-side electricity price forecast.

This paper examines and explains the development of electricity prices by means of a supply mix. It covers feed-in quantities of biomass, lignite, hard coal, gas, oil, oil shale, peat, geothermal energy, waste, water, solar, wind and other renewable energies. The methods used are multivariable linear regression, ARIMA(X) [4] and artificial neural networks (KNN). For KNNs, a distinction is made between classical feed-forward networks, in the form of a single-layer perceptron (SLP) and multi-layer perceptron (MLP), and recurrent networks (Hopfield 1982), or more precisely long-short term memory networks (LSTM) [17]. The two variants MLP and LSTM are designed as deep learning networks. Deep learning generally stands for a special form of KNN, which is characterized by well thought-out successive layers with a higher number of units each [30, 13]. In MLP as well as in LSTM, the activation of units into the hidden layer is done by means of rectifiers [15, 16], which achieve better training results especially in deep networks [12]. The regression as well as the ARIMA(X) model serve as benchmarks for the comparison with the KNN.

The work is structured as follows: The second chapter reports on the state of research. The third chapter presents the sample and methodology. In the fourth chapter the models and the resulting results per model are presented and explained. The article closes with a summary.

2 Prior Research

For European markets, the electricity price is determined by supply and demand. A large number of papers already exist on demand-side electricity price forecasts. Weron [34] provides a general overview of a variety of methods and proposals as well as an outlook for the next decade. The author divides the models into five categories: multi-agent models, basic (structural) models, models in reduced form (quantitative, stochastic), statistical models and computer-aided intelligence models. With artificial neural networks, one, if not the heavyweight of artificial intelligence in electricity price forecasting is becoming increasingly important. An up-to-date and detailed overview in this respect is provided by Meier et al. [25], who take the electricity price forecast of the European market as a starting point, using different models such as ARIMAX, regressions and different KNNs, mainly using autocorrelative and non-linear correlative time series characteristics such as day, week and year related seasonalities. For probabilistic electricity price forecasts, Dudek [9] proposes an approach based on feed-forward networks. Unlike Dudek, Zhang [36] combines the

advantages of a non-linear KNN and a linear ARIMA model to leverage the strengths of both methods and provide greater predictive power. In the same way, Filho et al [10] follow a hybrid approach tailored to the Brazilian market. The results of this approach are compared with classical models such as ARIMA, GARCH, Exponential Smoothing and KNN. For a forecast period of 24 and 36 weeks, the hybrid model clearly outperforms the forecast accuracy of the other models mentioned. However, the lack of general validity for other markets remains to be mentioned. Raviv et al [28] examine the forecast accuracy of uni- and multivariate models for hourly electricity prices of the North Pole market. The forecasts are based on average prices for the next 24 hours. The multivariate models perform significantly better, according to an up to 15-20% lower RMSE. Here too, the question of general transferability to other markets remains open.

Relatively few studies deal with a supply-side electricity price forecast. Huisman et al [19] deal with hourly electricity prices on several day-ahead markets. When looking at hourly electricity prices, the authors, like Raviv et al. [28], also consider the simultaneous submission of electricity prices and the formation of an average price for 24 hours on one day to be inappropriate, since hourly electricity prices do not follow a time series process. For this reason they model a panel model with 24 cross-sectional hours.

Nowotarski and Weron [26] use a quantile regression for electricity price forecasts. In contrast to other statistical analysis methods, quantile regression allows the use of many distributions without restrictions. This flexibility also makes this approach suitable for forecasts, which is reflected in low forecasting errors. Díaz et al. [8], who use quantile regression, also use an hourly electricity price forecast for the Spanish market.

Contreras et al [6] use ARIMA(X) models for price forecasts of the Spanish and Californian markets. The central result of this work is the effect of the strength of the correlation between the price and the explanatory variable on the inclusion of other explanatory variables as well as on the forecast accuracy. In case of a strong correlation, the average daily mean error is between 5% and 10%. If the correlation is weak, additional explanatory variables have no significant effect on the forecast.

For the Colombian market with hourly electricity prices, Marin et al. [24] find that ARMAX and NARX (non-linear autoregressive neural networks) lead to similar prognosis values.

ARIMA(X) models are often used in the literature as a benchmark to make the results of KNN approaches transparent. Keles et al. [21] investigate the advantages of MLP compared to ARIMA(X), whereby the KNN has lower prediction errors.

Singhal and Swarup [31] also believe that an MLP is the most appropriate means of daily electricity price forecasting. This is characterised by the mastery of complex interrelationships of given factors such as price and historical load.

Gökgöz and Filiz [14] are setting up 400 MLP models for the Turkish market, which differ in the number of units and various activation functions. The most suitable model has an average absolute percentage error (MAPE) of 9.76%.

Li et al. [23] also focus on the investigation of the properties of MLP for forecasting price time series. For shorter time intervals the KNN provide a higher accuracy of the forecast values than comparable ARIMA models. Overall, the forecast accuracy of the MLP amounts to more than 80%.

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Table 1. Literature review of supply-side electricity price forecasts

author(s)	View		Further models			KNN			Propa- gation		Activation			Explanatory Variables						
	Offer page	Demand side	ARIMA	Regression	Other	MLP	Recurrent	LSTM	Linear weighted	Other	Linear	Logistic	Tangent hyperbolicus	Other	Price lag	Time	Date	Renewable energy	Fossil energy	Other
Marín et al (2018)	•		•						○		•			•		•				
Nowotarski and Weron (2015)	•			•											•	•				
Contreras et al (2003)	•	•	•												•	•				
Díaz et al. (2019)	•	•		•													•	•		
Huisman et al. (2007)	•	•			•										•	•				
Keles et al (2016)	•	•	•			•			○		•	•		•	•	•	•	•		
Peng et al (2017)	•	•						•	○		•	•			•	•				
Trotter and Kemfert (2007)	•	•			•											•	•			
Singhal & Swarup (2011)	•	•				•			○		•		•		•	•				
Gökgöz and Filiz (2016)	•	•				•			○		•	•			•	•				
Catalão et al (2007)	•	•				•			○		•		•			•				
Weron (2014)		•																		
Raviv et al (2015)		•	•	•		•	•		○					•	•	•				
Al-Saba and El-Amin (1999)		•	•			•			○		○	○				•				
Dudek (2016)		•				•			○		•	•								•
Meier et al (2019)		•	•	•		•			○		•	•		•	•	•	•			
Filhoa et al (2014)		•	•			•			○		•					•				
Zhang (2003)		•	•			•			○		•						•			

Legend: • used ○ subordinated

3 Sample and Methodology

3.1 Data

The Association of European Transmission System Operators for Electricity, ENTSO-E for short, represents 43 electricity transmission system operators from 36 countries, including Germany, Spain and France. Since the introduction of Regulation (EU) No 543/2013 of 14 June 2013, data providers and owners of data from the European Member States have been required to present information on electricity generation, use, transmission and balancing on the ENTSO-E transparency platform.

The energy quantity data required for the forecast models are taken from the ENTSO-E transparency platform. The data is derived from the query settings "Generation" and "Actual Generation per Production Type" as well as "DE-AT-LU" for the period from 01.01.2015 to 31.01.2018. The sample comprises the quarter-hourly available feed-in quantity in megawatts (MW) of 20 energy types: biomass, lignite, gas produced from coal, gas, hard coal, oil, oil shale, peat, geothermal energy, hydropump storage, run-of-river power plant, water reservoir,

marine, nuclear, other, solar, waste, other renewable energies as well as wind offshore and wind onshore. The corresponding hourly electricity prices are from the European Energy Exchange EEX. Due to the different compression levels of the feed-in quantity (quarter-hour) and the electricity price (hour), the average of the quarter-hourly feed-in quantities is formed for the respective feed-in quantity per hour for the purpose of temporal adjustment on an hourly basis. To take the time component into account as a predictor, dummy values are integrated for the hour, weekday, and month.

The following *Fig 1.* shows the course of the electricity price.

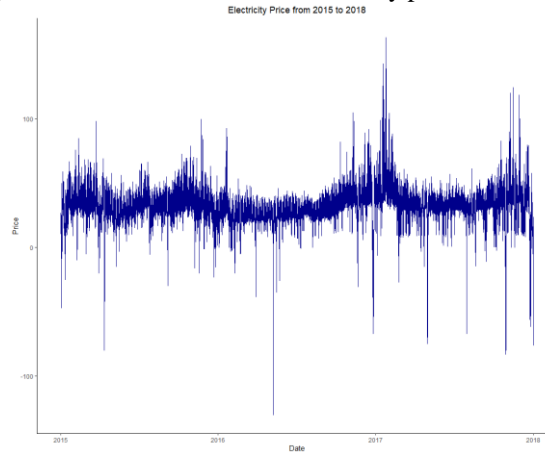


Fig 1. Course of the electricity price of the entire data volume

3.2 (Pre-) Processing of the Data

The entire data volume is first subjected to pre-processing. Missing values are imputed on the basis of spline interpolation. The time predictors month, weekday, and hour are extracted from the date and dummyfied. This results in 11 dummy variables for the month (January to November), 6 dummy variables for the weekday (Sunday to Friday) and 23 dummy variables for the hour (0:00 to 22:00). The data set is then divided into a training data set and a test data set, as usual for KNN.

For the training data set, a Kwiatkowski-Phillips-Schmidt-Shin (KPSS) test is performed, which provides the number of differentiations to establish stationarity. The electricity price of the training and test data set is differentiated once according to the result of the KPSS test. A partial autocorrelation function (PACF) analysis of the training data yields a significant number of lags (period-weighted time series) of 5. The use of Auto-ARIMA [20] confirms these results. The course of the electricity price differences can be seen in the Fig. 2.

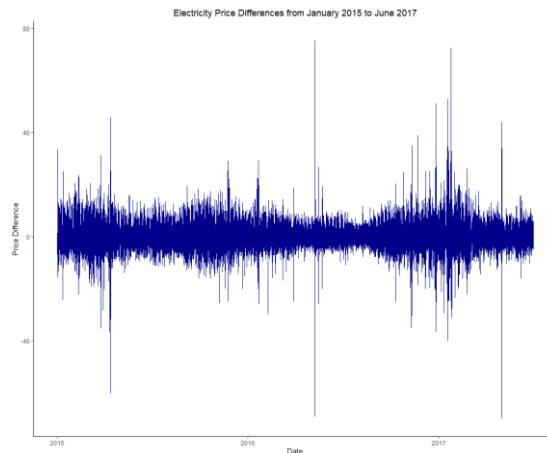


Fig. 2: Course of the electricity price differences of the training data volume

Then both sets of data are normalized using min-max scaling to transform the values of all predictors - except the dummy variables - into the range 0 to 1. For the test data set, the scaling factors (min, max) of the training data set must be used. The dummy variables, on the other hand, are subjected to an effect coding. The usual procedure in statistics for dealing with categorical characteristics using 0/1 coded dummy variables may prove problematic for KNNs and lead to suboptimal solutions in the adaptation of a KNN. Strictly speaking, the number 0 is regarded as critical. A mathematical proof can be found in Sarle [29]. Instead, he argues for an effect coding with -1/1 coded dummy variables.

Within the framework of the investigation of the training data set for model maintenance, a k-fold cross validation [7, 11, 22] in the form of a "sliding window" is used to optimize the hyper-parameters of the CNN. In k-fold cross validation, the entire training data set is broken down into k individual, equally sized parts, the so-called folds. Usually the folders are selected randomly. In time series, however, data sets of the training data set that follow each other directly must always be combined into a fold, since the order of the data sets is decisive and must not be confused. With the Form Sliding Window, when training a KNN one fold per iteration is successively used as training data set and the immediately following fold as validation data set and the MAE (mean absolute error) per epoch is calculated. After the end of the training of a KNN, the average of all MAE values per epoch can be determined. From the visualization of these values (x-axis: epoch; y-axis: $\bar{\text{MAE}}$), the number of epochs for which the MAE is minimal can be read. This number of epochs is considered the optimum number of epochs. Subsequent epochs should not be taken into consideration, as the increasing MAE value indicates an overfitting. The optimal number of epochs is used to generate the final or generalized model based on the total amount of training data.

The RMSE (root mean square error) is used to compare the prediction quality of the respective final models, ARIMAX, Regression, SLP, MLP and LSTM, with the test data set. This metric is considered the standard measure for metric quantities in the literature[34].

4 Results

The first KNN is an SLP, which can be regarded as a classical regression model substitute. The 4-fold cross-validation has resulted in an optimal epoch number of about 30. Repeated training of the SLP yields an RMSE of 4.07 for the training data set and 4.77 for the test data set. The results are shown in the Fig. 3

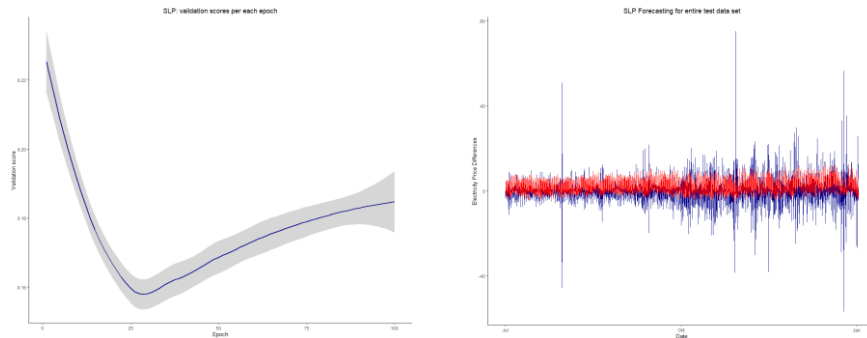


Fig. 3: Results SLP, left the cross validation, right the forecast

The second KNN is a deep learning MLP with three hidden layers (128, 64 and 32 units) and respective rectifier activations. The 4-fold cross-validation has resulted in an optimal number of epochs of about 60. Repeated training of the MLP yields an RMSE of 2.88 for the training data set and 4.13 for the test data set. The results are shown in the Fig. 4.

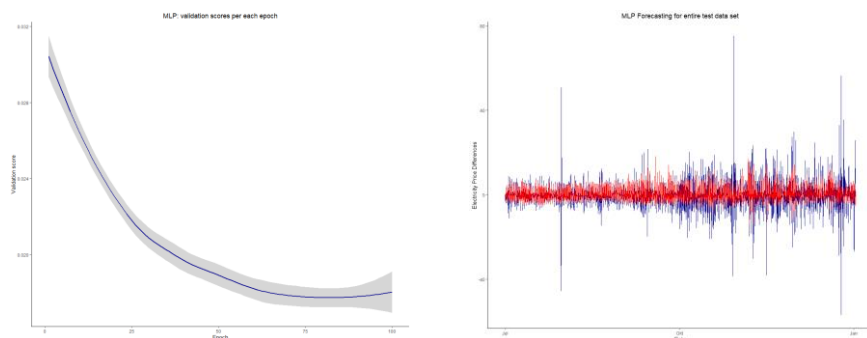


Fig. 4: MLP results, cross-validation on the left, forecast on the right

The third KNN is a Deep Learning LSTM with also three hidden layers (128, 64 and 32 units) and respective rectifier activations. The 4-fold cross-validation has resulted in an optimal number of epochs of about 50. Repeated training of the LSTM provides an RMSE of 2.79 for the training data set and 4.09 for the test data set. The results are shown in the Fig. 5

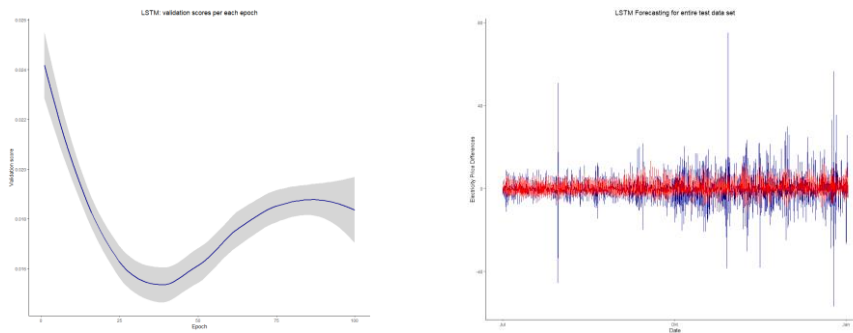


Fig. 5: Results LSTM, left the cross validation, right the forecast

The following **Error! Reference source not found.**the results and presents the RMSE values of all models used for different amounts of test data. A one-week test period is selected for each quarter to take into account seasonal variations in the test data sets. The four test datasets cover the periods 1.1.-7.1.2017, 1.4.-7.4.2017, 1.7.-7.7.2017 and 1.10.-7.10.2017.

Table 2. RMSE values of all models

RMSE for test periods					
Model	Jan 2017	Apr 2017	Jul 2017	Oct 2017	total
ARIMAX	4,37325	2,51524	2,24350	4,61178	
Regression	4,32585	2,55180	2,23342	4,63412	
SLP	4,81282	2,67128	2,38036	4,82037	4,77
MLP	4,06866	2,25496	2,27558	4,69374	4,13
LSTM	4,29037	2,36789	1,97528	4,99047	2,79

In the regression analysis, the variables lignite, gas, hard coal, oil, hydropump storage, water, solar, wind offshore, wind onshore, months 5-8, all days of the week and all hours are significant predictors for the forecast model.

In the overall view of the prognosis models, none stands out as dominant, even if MLP and LSTM deliver noticeably better results than the simpler prognosis methods, this seems to vary with the seasons, as already known from other studies.

5 Conclusion

This paper examines and explains the supply-side electricity price development, taking into account a large number of fed-in electricity quantities as well as relevant time factors in the form of month, weekday and hour. ARIMAX, regression and different KNN are used. The best forecast results are achieved by the LSTM, which, as expected, is best able to deal with time series. However, depending on the season to be forecast, it is not yet completely convincing.

Since supply-side electricity price forecasts are still very much underrepresented in the literature, the present study can serve as a basis for further replication and comparison studies.

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Neuro-Genetic Hybrid System for Management of Organizational Development Measures

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Abstract. Current practical experience in measuring the effectiveness of organizational development activities is largely based on the evaluation of surveys. In this paper we present an approach based on an artificial neural network with elements of a fuzzy approach and a genetic algorithm to control organizational development. Based on genetic algorithms, the organizational development measures are initiated, selected, combined or mutated with the goal of finding the best possible solution for each concrete case. Since many variables have the uncertain set of their values, the use of a hybrid neuro-fuzzy mechanism makes it possible to analyze the behavioral components up to the combinations of needs and thereby select the appropriate organizational development measures. The system is designed to ensure the long-term effectiveness of organizational development measures. We supplement the previously known measures of organizational development with technology-based in order to increase the degree of automation in practice. This article is intended as an orientation for other scientists who are researching the same topic and are interested in the current state of the art, as well as for companies who want to ensure compliance with internal company rules using digital tools.

Keywords: neuro-genetic hybrid system, organizational development, fuzzy logic.

1 Introduction

Organizational development is a long-term continuous, planned process of optimizing attitudes and behaviors of organization members to achieve organizational goals. This process requires tremendous methodological knowledge of the participants and the commitment to change. Since changes in the state of the object of organizational development are often not clearly measurable over time, the genetic application with elements of fuzzy logic is particularly beneficial. Several already published studies offer approaches for management organizational change in general [1, 6, 8, 16, 18], employee performance [4], behavior [2, 15] using the technologies of artificial intelli-

gence. These indicate high-quality approaches, some of which could also be applied to goals defined by us, but do not cover the entire range of the problem. Based on artificial intelligence, we have developed a model with three modules for organizational development. The first module is used to diagnose and record the current state of the organization, analyze the received data, and determine long-term measures for organizational development. The second module gradually monitors the results of the implemented measures, introduces and implements corrections. The third module has the main function of managing the system. The functions of the first two modules were realized through hybrid neural networks, partly with fuzzy weights. We apply the genetic algorithm to determine the behavior of individual (especially immaterial) multi-level variables. The reason for using the neurofuzzy system is on the one hand partially non-linear dependencies of the variables (their weighting), and on the other hand we implement the genetic approach to reach the system's ability for learning and adaptation. Although organizational development is primarily concerned with the behavior of organization members, the variables we measure are more than directly related to people. In this article, we limit our scope to the neuro-genetic hybrid system and present an example of just one functionality of the system that serves as the basis for in-depth behavioral correction.

2 Methodology

Neuro-genetic hybrid systems are mainly used for complex systems that, for example, map human behavior (subsystem investigated by us). These have a multilevel approach to capture, analyze and predict various processes or to offer a solution for a specific case [10-12, 14, 17, 19]. In our system for management of organizational development, we consider several subsystems, ranging from corporate performance and standards system to group behavior or individual motivation. In general, the neuro-genetic hybrid system works according to the following principle (**Fig. 1**):

- Genetic algorithm: the current element population receives three types of sequential rules of genetic operations to form the next generation of elements. A distinction is made between selection, crossover and mutation (**Fig. 2**). According to the first rule, a parent element from which the child elements follow is defined. The second rule defines the parent pairs that will create the respective children. The third rule determines the random changes to each parent element for the later creation of the child elements. Artificial neural network: The child elements enter the artificial neural network model as an input variable. In the artificial neural network model, the input data is analyzed and the option is outputted.
- Decoded strings from the current population enter the fitness calculation with the prediction results.
- The optimum variables are determined from the fitness evaluation.
- In case of non-conformity (data no longer correct or sufficient), the procedure is repeated.

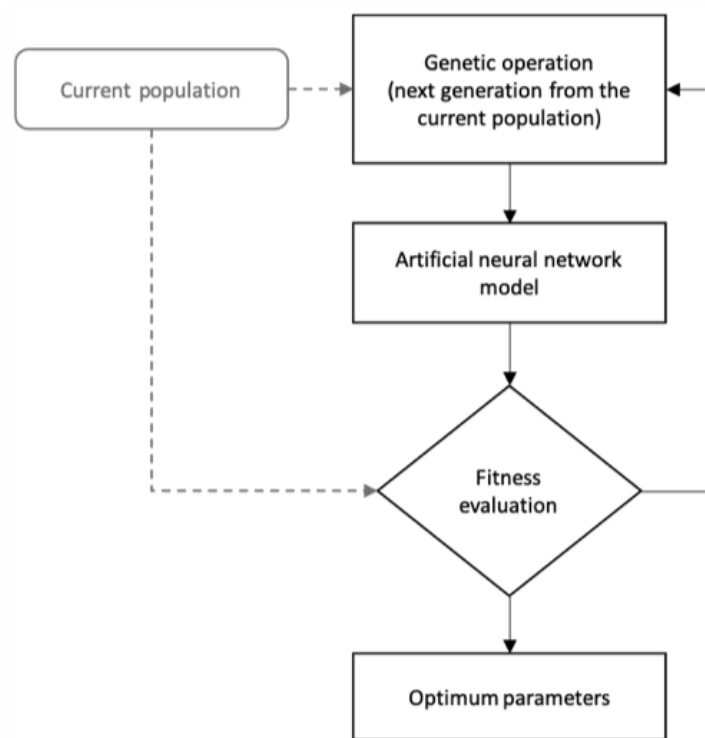


Fig. 1. General functional principle of neuro-genetic hybrid system

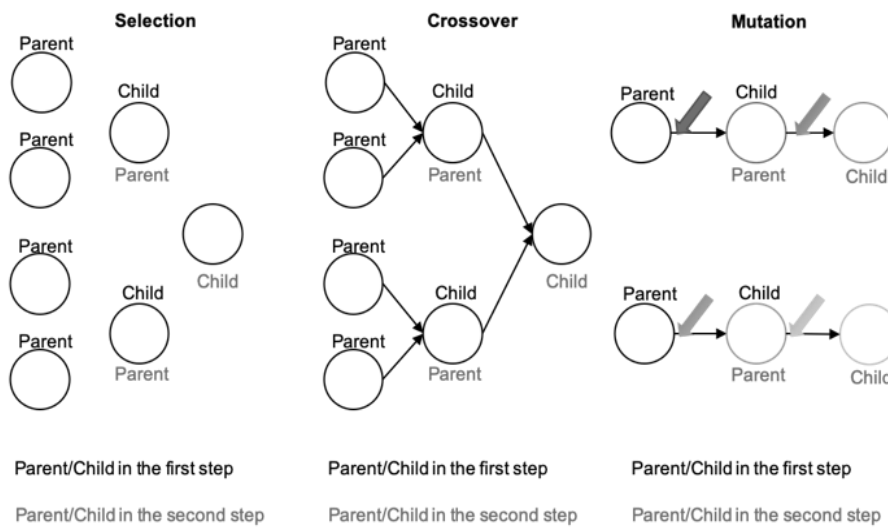


Fig. 2. Types of rules for the definition of next generation from current population

Since the majority of the variables are linguistic variables with multiple meanings, we use fuzzy logic to describe the relations in the system.

3 Results

The primary goal of organizational development is to ensure the long-term evolutionary improvement of the human factor as an organizational component to achieve organizational goals i. a. by influencing behavior. The individual is a member of a group within an organization and is therefore considered in connection with other group members (the individual is the lowest level in the organizational chain). At the same time, the group is a part of the department/area/the whole organization (the middle level in the organization chain). Thus, within the development of the organization, the group is also considered a member of the organization with all its connections. Since the form of the organization and the number of levels vary, we break the chain of organization after the third, the highest level - the organization itself (the departments, units and divisions are excluded, as they are considered as organizations within organizations). Consequently, the organizational development measures are focused on the single elements of the organizational system, their internal and external relationships, and the organization as a whole. Since the planned improvements are intended to be irreversible, the organizational development measures per se have the learning character. Most known methods of organizational development are limited to such motivation and behavior controls, that influence employees and groups directly or indirectly live, from print or digital media (meetings, workshops, employee information, leaflets, intranet contributions, etc.). Our approach refers to the control of motivation and behavior by providing timely actual information and assistance, where wrong behavior or work performance is excluded. This can be achieved through the digital assistant systems.

Since our organizational system is very complex, we have established several subsystems with complex structures [9, 18]. The neuro-genetic hybrid system, which is designed as a heuristic algorithm for searching the solution for optimization and modeling by selecting and combining of variables. In this case the neural network searches the potential solutions of multi-level fuzzy sets for further use by the genetic algorithm. The genetic algorithm consists of initialization, selection, cross-over and mutation. **Fig. 3** shows the principle of the system. In the context of organizational development, certain measures are performed, for example, informing employees about the new corporate values. After a certain period of time, the employee or group of employees shows behavior that does not correspond to the expected behavior. In the system, the behavior is split up into corresponding components. These are analyzed in steps and new corrective measures are offered. The employee or group of employees executes the measures. If the second measure is better than the first one, it is selected as one of the most effective measures in the measure pool. The next step is to improve the behavior of the employee or group of employees. To do so, the measures from the measure pool are combined or modified. If the behavior is not successful after the implementation of new measures, the process starts again.

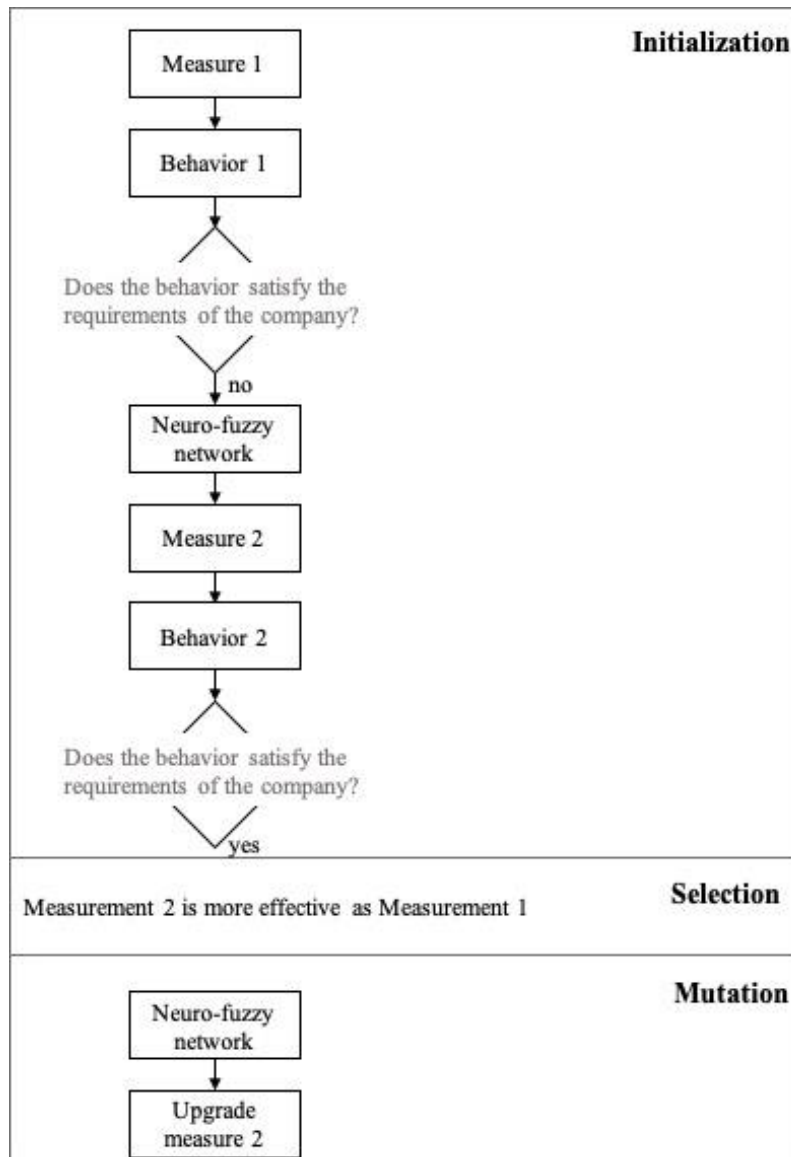


Fig. 3. Basic principle of the developed neuro-genetic hybrid system (example - mutation)

Input variables are collected in two ways: through video, audio or text recording mechanisms (self-developed, based on Microsoft tools) and from the connected performance measurement systems. In the first way e.g., emotions and modus operandi are recorded, in the second way e.g. work productivity and error rate are measured. The incoming information is analyzed in a fragmented way. For example, facial expressions with different voice positions or gestures are interpreted differently.

Furthermore, an example for the application of the neuro-genetic hybrid subsystem is presented.

The company is positioning itself as diversity-oriented. Cosmopolitanism and acceptability belong to the organizational values. During a conversation between employees in a working group, our system several times detects racist context (unacceptable words) that is offensive to human dignity. This resists one of the organizational goals, the stabilization of organization-compliant behavior of employees (in this case focused on behavior with colleagues and superiors, employee as part of the company, individual performance for overall goal).

The conversation is recognized as an emotional act. The variables of the act are the type of activity (conversation, by voice recognition), quality (in this case unsatisfactory, because of the recognized context), duration (in this case medium ($2 < x < 30$ minutes)), and iterations (in this case multiple), see **Table 1**. In this case, certain context components (unacceptable words) are recognized as hints. The hints serve as markers for variable values and indicate the allowed limits. The captured emotion is analyzed as happiness (through few iterations of smiles by face and voice recognition). Such behavior is declared as neutral conversation with unacceptable words.

Table 1. Act variables

type of activity	quality	duration	iterations
conversation	exemplary	brief	one
monitoring activity	desirable	medium	few
writing activity	good	long	multiple
manual activity	satisfying	very long	combination
coordinating activity	unsatisfying		
specific activity	bad		

In the case described, we refer to a certain type of activity. In other cases, for example, when the performance data of the person (speed and quality of the assembly, skill level of a working step) is collected externally, other variables will be input into the system. The goal of our system is to evolutionize the activity in small steps and to achieve the learning effects by applying appropriate measures. In other words, we intend the gradual implementation of the measures, not only to avoid unacceptable activities, but also to direct the underlying motives and needs to the benefit of the company. Here the fitness value correlates with the desired state of the act. Therefore, the first population refers to the quality, duration, iterations on the one hand, and emotion on the other hand.

The variables of the current acts flow into the neural network. This is necessary to select the optimal measures in the neural network by defining the corresponding motives and needs. The motivation and accordingly the needs are mainly derived from the type of activity, its quality and the hints. Kotlyarov [7], Petrenko and Tabaharnyuk [13] in their model of motivational space for organizational education, guided by Draker's theory, propose a three-dimensional vector space (expediency, result,

effect) to describe the motivational strategy of an organization, group and individual. We have partially adopted and expanded their approaches.

Special attention should be given to the phases of the motivation need cycle, as these are directly related to the motivation optimum and therefore activate the motivation behavior subsystem [5, 20]. In the described scenario, the person is in the phase of actualization of the need, which is combined with an increase in emotional tension, a feeling of lack, a desire to do something, a desire for activity that is not directed. In this case, the measures proposed and applied by our system must correct the behavior of the person according to the organizational values and change the phase from the need-motivational cycle, either in the direction of the search phase or in the direction of the latent phase.

Thanks to the neural network, the system learns to manage special complex problems. The main layers refer to behavior components, motivation and needs.

- The behavior in our model is represented as a set of activities with defined vectors of acts and emotions. The act, in turn, is defined by the function of weighted motives. As a result, scalars of actions can acquire positive and negative integer and fractional values:

$$p \in \mathbb{Q}; \underline{P} = \{p_1 \dots p_n\}; p_n = \sum_{j=1}^{\infty} \sum_{n=0}^1 m_j g_n \quad (1)$$

- Weighting G is a complex function of dependence of key indicators, such as the value of expected result, target density, resources spent, external oppressive or binding factors, opportunities, etc. on their correlation ratio. These determinants reflect the views of H. Heckhausen's theories as well as those of J. V. Brem and E. Heckhausen. A. Self [3] and depend on activity type (are defined individually). Since this model investigates not only personal but also environmental factors, they are considered as an indicator of the influence on the force of the motive. Weighting takes the form of a vector of positive scalars of integers or fractional numbers:

$$g \in \mathbb{Q}; G = \{g_1 \dots g_n\}; g_n = \frac{\sum_{l=0}^1 \sum_{i=1}^{\infty} b_l w_i}{\sum_{i=1}^{\infty} w_i} \quad (2)$$

- Motive M is a function of need: the total number of appropriately prioritized needs reproduces the motive vector. Since a motive is not always positive, its individual scalars can be negative fractional numbers (c is a need dimension function). The mathematical content of a motif is expressed as follows:

$$M \in \mathbb{Q}; \underline{M} = \{m_1 \dots m_n\}; m_n = \pm \sum_{n=1}^{\infty} c_n a_n \quad (3)$$

- Need a in mathematical context is a positive integer. Needs that define a motive are represented as vector A:

$$a \in \mathbb{N}; A = \{a_1 \dots a_n\} \quad (4)$$

Our system is based on the combined approach of motives and needs. Selection of needs for motivation combinations is based on the theories of Maslow, McClelland, Alderfer and Herzberg. In the described case, the act is based on the motivations of identification, authority, prosocial motivation and consequently the fundamental needs of self-affirmation, acknowledgment, authority and security with corresponding degree of involvement. The degree of involvement shows how deeply the need is present in the motivation.

The concrete IF THEN rules for the motivation-need relationship are shown in **Table 2** (IF “need 1” = “degree of influence x” AND ”need n” = “degree of influence y” THEN “motivation 1” AND “motivation n”). In most cases, the behaviour is due to the combination of several motivations and therefore depends on multiple needs.

Table 2. Overview of dependencies in motivation-need relation on employee level

need	motivation							
	identification	self-affirmation	prosocial	authority	achievements	self-development	procedurally sub-stantive	affiliation
self-affirmation	●●●●●	●●●	●●	●●●●	●●●●	●●●●	●●●●●	●
acknowledgment	●●●	●●●●●	●●●●	●●●●●	●●●	●●	●	●●●●
respect	●●●	●●●●	●●●●	●●●●●	●●	●●	●	●●●
identification	●●●●	●●	●●●●	●●●	●●●●●	●●	●●●●	●●
affiliation	●	●●●●	●●●●●	●●	●●	●●	●	●●●●●
development	●●	●	●	●●●●	●●●●●	●●●●●	●●●●	●
authority	●	●●●	●●●	●●●●●	●	●	●	●
achievement	●●●●	●	●	●●●●	●●●●●	●●●●●	●●●●	●
involvement	●	●●●	●●●●	●●	●●	●	●	●●●●●
security	●	●	●●	●●●●	●●	●●●	●	●●
physiological	●	●	●	●●	●●	●●	●	●

- - no or very weak involvement
- - weak involvement
- - medium involvement
- - strong involvement
- - very strong involvement (dominant need)

Each level of neural network has its componets, with the generalized form (Помилка! Джерело посилання не знайдено.):

– The abstract element E (in our case need/motivation/act etc.) has the following form:

$$E(x) = \frac{1}{1 + e^{(\pm a(x-b))}} \quad (5)$$

– Therefore, the rule β becomes the general form:

$$\beta = E_1 \wedge E_2 \wedge E_3 \quad (6)$$

– and the output is accordingly:

$$o = E_1^{-1}(\beta) \quad (7)$$

– The total system output is expressed by the formula:

$$o_0 = \frac{\sum_{n=1}^{\infty} \sum_{k=1}^{\infty} \beta_n o_k}{\sum_{n=1}^{\infty} \beta_n} \quad (8)$$

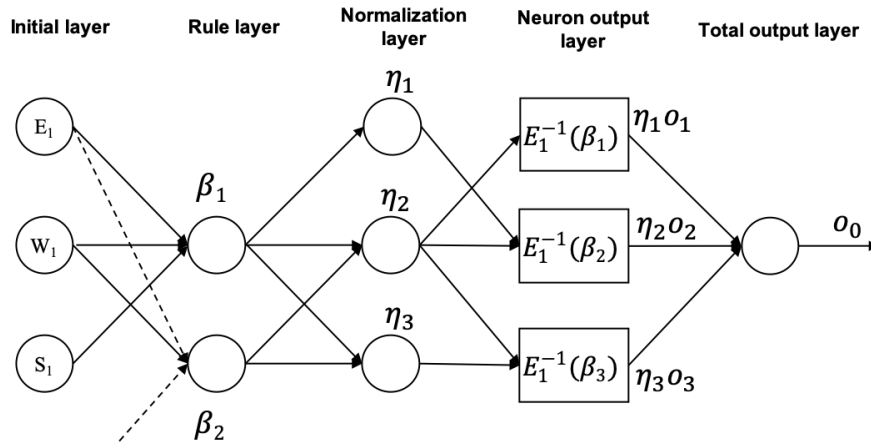


Fig. 4. Part of the artificial neural fuzzy network for an element level (e.g. motivation)

In general, individual layers can be described as follows:

1. Initial layer: The outputs of the nodes are degrees in which the given inputs satisfy the functions associated with these nodes.
2. Rule layer: Each node calculates the intensity of the rule. All nodes are marked with T and can be selected to simulate logical AND.
3. Normalization layer: Each node normalizes the intensity of the rule:

$$\eta_j = \frac{\beta_j}{\sum_{n=1}^{\infty} \beta_n} \quad (9)$$

4. Neuron output layer: Neuron output is the product of normalized rule intensity and individual rule output:

$$\eta_n O_n = \eta_n E_3^{-1}(\beta_n) \quad (10)$$

5. Total output layer: Single output neuron calculate the network output:

$$O_0 = \sum_{n=1}^{\infty} \eta_n O_n \quad (11)$$

The neural network consists of such elements, where the output of one level corresponds to the input of the other level. In case one of the variables does not occur, it is still recorded with minimum value.

In the case of usage of unacceptable words, different measures are implemented one after the other, in the order of information - warning - sanction. In this case, the first step is general information (as a voice reminder or on the display screen): "In this company such phrases are not being used". Next is "Please use the following words instead of (unacceptable words)...". The employee is subsequently warned of the following "Any unacceptable words will be punished by (certain measure)". If these measures do not work, the sanction will follow. At the same time, measures are being taken to adopt new behavior patterns in order to achieve the organizational goal of long-term stabilization of employee behavior.

The following system can not only be applied to commercial and public organizations, but can also be used for integration projects of diverse groups.

4 Conclusion and Discussion

The system we describe should only be seen as part of the overall organizational development system, which cannot be described within an article because of its complexity. The whole system offers the monitoring of organizational development at all levels of the company and therefore provides continuous improvement.

The main strength of neuro-genetic hybrid systems with fuzzy neurons and rules is that they are universal approximators. Nevertheless, this method also has disadvantages in the implementation of organizational development, such as very long processing time and uncertain convergence. Furthermore, the limitations of the system proposed by us include the complexity, high data volume and preparation effort on the organization side, as the system depth and organizational development measures have to be created individually by each company.

The main motivation for the use of such systems is the timely integration of appropriate measures in order to achieve the organizational goal in an optimal way.

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Do Commodities Determine the EU Emission Allowances Price?

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Abstract. This paper presents an analysis of the influence of gas, coal, electricity and Brent (crude oil) prices on the EU emission allowance price by means of a vector autoregression analysis. Statistically significant influences on the price of CO₂ emission allowances can be identified for all energy market variables examined, except electricity prices. Thus, the present analysis supports the assumptions of earlier publications that the influence of the energy market on the European Emissions Trading System (EU ETS) is decreasing and that the efforts of the European Commission are having an effect. The EU ETS is designed to stimulate the reduction of emissions by setting caps and to create monetary incentives for investment in new, low-emission technologies by trading emission allowances. However, the allocation efficiency of this system is conditional on the relative price stability of the emission allowances, as this is the only way to make reliable forecasts for risk calculations and investment decisions by companies. Using a vector autoregression model (VAR), this paper demonstrates significant influences of energy prices on the European Emission Allowances (EUA) price in the third phase of the EU ETS.

Keywords: CO₂, emission allowances, emissions trading, energy prices, vector autoregression, VAR

1 Introduction

The European Emissions Trading System (EU ETS) was implemented in all 28 EU member states on 1 January 2005. As a cap-and-trade system, it sets an upper limit for the total amount of greenhouse gas emissions permitted in industry, but allows trading of emission allowances between companies within this quota. The upper limits are set individually by the EU member states with the aim of reducing the permitted emission quantities over the course of the years [9].

The possibility of buying and selling allowances allows companies that produce particularly low greenhouse gas emissions to benefit, as they can sell surplus allowances to other, less efficient companies. In a stable trading system, this can create incentives for companies to invest in the conversion of their production facilities so that they can refrain from purchasing emission allowances in the future. In a functioning market, the prices of emission allowances thus reflect allocation-efficient investments in climate protection.

For the incentive systems described above to work, a stable market for emission allowances is necessary. This became clear when the economic crisis of 2008 abruptly reduced the CO₂ emissions of companies, which in turn led to a massive oversupply of emission allowances and caused the price of these to fall [9].

2 Trading Periods of the EU ETS

Emissions trading takes place in allocation phases lasting several years (see Fig. 1) in order to compensate for fluctuations, for example as a result of extreme weather conditions, and to create longer-term investment security. With each subsequent phase, the system was successively implemented and stabilized in the market.

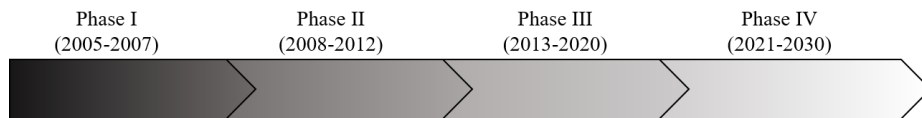


Fig 1. The phases of the EU ETS.

In Phase I, a price for carbon emissions was set that allows EU-wide trading and sanctions for exceeding the ceilings were implemented. The emission allowances were initially distributed to the companies free of charge, while at the same time an infrastructure necessary for monitoring was created. In the absence of reliable emissions data, estimates were used to determine the number of allowances to be issued. However, as these were clearly too high, the price of the emission allowances fell to zero in 2007 [9].

In Phase II, the quantity of allowances distributed free of charge was reduced, as were the emission ceilings of the countries. In addition, three new countries, Iceland, Liechtenstein and Norway joined the emissions trading scheme. The penalty price per tonne of CO₂ for exceeding the ceilings was more than doubled. However, due to the economic crisis during this period, the price of emission allowances fell significantly [9].

In the currently ongoing third phase of the EU ETS (as of March 2020), the national caps have been replaced by an EU cap. The emission allowances not distributed free of charge will be auctioned and additional industrial sectors and emission gases will be covered. In addition, the market stability reserve was introduced. As a short-term solution, the auctioning of a total of 900 million allowances in 2014-2016 was postponed to 2019 and 2020. The market stability reserve, which was implemented in January 2019, represents the long-term solution. In future, this reserve will absorb surpluses in the allowances market in accordance with defined rules and, if necessary, distribute allowances in the event of a shortage [9].

A further reduction of the ceilings and further strengthening of the market stability reserve is planned in Phase IV. In addition, from 2023 onwards, emission allowances from years prior to the previous year of the current trading period are to expire [9].

In order for the EU ETS to serve as an incentive scheme for investment in technologies to reduce greenhouse gas emissions as described above, it is necessary that the scheme provides a stable price. Only with this price as a basis can companies make conscientious investment decisions. Thus, important practical implications can be derived from this study.

This paper will use vector autoregression analysis (VAR) to analyse the interactions between the four most important energy prices, electricity, gas, Brent (crude oil) and coal, and the price of emission allowances. These four factors represent important economic indicators in the energy sector and are therefore suitable for examining the vulnerability of the EU ETS to minor economic fluctuations. This study covers the period from 30 September 2013 to 1 October 2019 and provides a more up-to-date analysis than the existing literature. Furthermore, existing theories for phase III of the EU ETS will be verified.

The present work is structured as follows: In the next section a short overview of the results of the existing literature is given. Based on the literature, hypotheses for the investigation are derived. In the third section the sample and the chosen methodology are presented. Then the results are discussed and a summary of the possible implications of the results is given.

3 Prior Research and Hypothesis Development

3.1 Prior Research

The literature on the dynamics and volatility of CO₂ allowances has grown rapidly during the first and second phase of the EU ETS (2005-2012) and flattened significantly with the start of the third phase of the EU ETS in 2013. This may be due to the fact that the system became established and prices have remained relatively constant since. Since 2018, however, the EUA price has risen significantly, reaching a record high in mid-August 2019, almost six times its September 2013 value. The variables influencing the price of CO₂ emission allowances identified in the literature to date are numerous and vary in their intensity from phase to phase.

Mansanet-Bataller et al. [16] concentrate in their work on the daily CO₂ price changes in 2005 in order to investigate the underlying rationality of price behaviour. For this purpose, the authors have analysed influencing factors on both the supply and the demand side of EUAs using different models. While the effects of national allocation plans on the price level of CO₂ emission allowances were not statistically significant in an intervention analysis, the influence of energy and weather variables on CO₂ price changes could be demonstrated. The authors applied OLS-regression and the Newey-West covariance matrix estimator, among other techniques.

Alberola et al. [2] have analysed the influences on the EUA price during the entire pilot phase of the EU ETS (2005-2007). Using the OLS method, the authors postulated an empirical relationship between changes in EUA prices and significant influencing factors such as commodities (Brent, coal, gas), electricity prices and weather conditions. The authors also show that the effects of the influencing factors on the EUA price

changed in the period 2005-2007 after two statistically determined structural breaks in the EU ETS in April 2006 and October 2006, which were caused by the publication of new market-relevant information. According to the authors, unforeseen temperature changes in extreme weather conditions play a greater role in EUA price changes than the temperatures themselves.

Bredin and Muckley [4] have investigated the extent to which several theoretically based factors such as economic growth, energy prices and weather conditions determined the expected prices for EUAs in the period 2005-2009. Using both static and recursive versions of the multivariate cointegration probability ratio test, the authors show that the EU ETS is a functioning market driven by these factors. Creti et al [8] confirm this result in a cointegrating framework by using the Dow Jones Euro Stoxx 50 as their stock variable.

Aatola et al. [1] have investigated the pricing of EUAs under the EU ETS and its price development during the first five years (2005-2010). For this purpose, the authors first developed a market equilibrium model for the emissions trading market and then tested it empirically using time series econometrics. OLS, IV and VAR models were applied. The time series of various EUA-related commodities and other relevant market fundamentals, such as electricity, steel, paper and mineral products, were used as explanatory variables. The authors were able to show that there is a clear and stable relationship between energy prices and the EUA price. About 40% of the price changes in the EUA futures price could be explained by these fundamentals. The most important determinant of the EUA price is the price of electricity generated in Germany, which has a large and significant influence on the EUA price. Other energy prices also influence the EUA price in a statistically significant way, but to a lesser extent.

Hintermann [13] investigated the interaction between the EUA price and marginal abatement costs during the first phase of the EU ETS (2005-2007). He found that Brent (crude oil) prices, electricity and economic growth indicators are important price drivers. However, due to the shorter time span in the study, his estimates showed less statistically significant coefficients than those of Aatola et al. [1]. Hintermann [13] also classified the coal price as not significant.

Chevallier [6] has investigated the interaction between EUA, energy and macroeconomic variables by specifying and estimating several Markov-switching VAR models for the period 2005-2010, extending in particular earlier work by Benz and Trück [3] on univariate Markov-switching modelling of EUA price series. In conclusion, Chevallier [6] found that the industrial development of a country has a positive influence on the development of the EUA price. In upturns, the EUA price rises as the economy picks up; in recessions, the EUA price falls as the capacity utilisation of manufacturing companies increases. In addition, the author postulates the price of fuel as the most influential variable, which shows influences on other energy prices in addition to the EUA price.

Hammoudeh et al. [12] use a quantile regression to investigate the effects of changes in crude oil, natural gas, coal and electricity prices on the distribution of CO₂ emission allowance prices in the United States in the period from 2006 to 2013. The authors found that an increase in the price of crude oil leads to a significant decrease in the price of CO₂ if it is very high; changes in the price of natural gas have a negative effect on

the price of CO₂ if it is very low but a positive effect if it is high; the effects of changes in the price of electricity have a positive effect on the price of CO₂ in the right part of the distribution and the price of coal has a negative effect on the price of CO₂.

In summary, previous research has shown that the level of the CO₂ emission allowances price is primarily regulated by the market mechanism of supply and demand on national exchanges [6, 7, 16]. Numerous influencing factors on both the supply and the demand side have been investigated in the literature.

The supply side is determined by the number of allowances made available by the state through national allocation plans (NAPs) in consultation with the European Commission [1, 6]. A certain price or a lower or upper price limit can be set directly when the allowances are made available. Furthermore, it is possible to influence the price of CO₂ emission allowances by regulating the quantity of allowances made available [12] or by setting an upper emission limit below the usual commercial emission level [2].

The demand side is characterised by a complex interaction of various influencing factors. In addition to weather conditions (temperatures, precipitation and wind speeds) [2, 16], economic activity (economic growth and activity on financial markets) [6] and the disclosure of institutional information [2], energy prices (coal, electricity, oil and gas) are seen as the main influencing factor [1, 2, 5, 6, 12, 13, 16, 17].

The following diagram provides an overview of the main factors on the supply and demand side that influence the formation of the CO₂ emission allowances price.

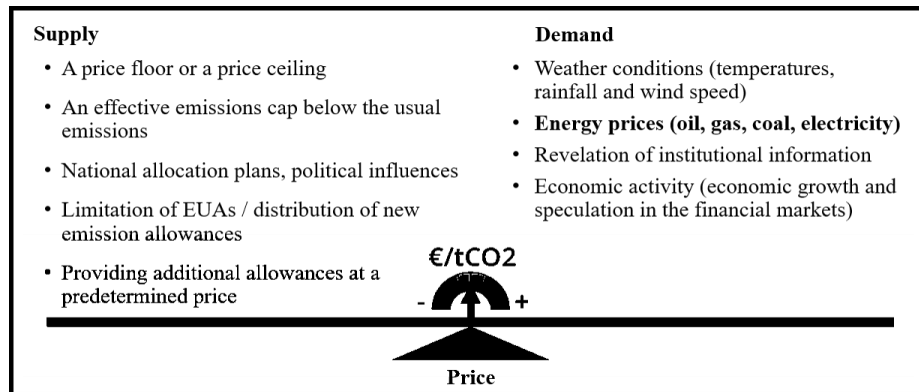


Fig. 2. Factors influencing the price of CO₂ emission allowances.

3.2 Research Gap

According to the existing scientific literature, the prices of Brent (crude oil), natural gas, coal and electricity were chosen as the most calculable price influencers on the price of emission allowances. In contrast to the existing literature, this study considers the period from 30.09.2013 to 01.10.2019. The year 2013 marks the beginning of the implementation of the third phase of the EU ETS, in which the instruments used led to a relative stabilisation of the prices for emission allowances from 2018 onwards (Fig. 4) and the interaction of the different market mechanisms.

3.3 Hypothesis Development

The following hypotheses can be derived from the results of the preceding literature:

Hypothesis I (H1): The price of Brent (crude oil) has a negative impact on the EUA price, since a high oil price reduces the demand for oil and thus greenhouse gas emissions. Consequently, an increase in the price of crude oil leads to a decrease in the price of CO₂ emission allowances [12].

Hypothesis II (H2): The coal price also has a negative influence on the EUA price [1, 2, 12]. If the coal price rises compared to other energy markets, companies have an incentive to change their energy mix to less CO₂-intensive energy sources.

Hypothesis III (H3): In the literature, the gas price is generally associated with a positive influence on the EUA price [1, 2, 16]. Hammoudeh et al. [12] differentiate further and state that an increase in natural gas prices has a negative effect on the EUA price if it is very low, while an increase has a positive effect if the EUA price is high. This effect is mainly related to the high degree of substitutability between gas and coal, which was also found in further investigations [2, 12, 16].

Hypothesis IV (H4): According to prevailing opinion, the electricity price has a positive influence on the price of EUA [1, 2]. According to Aatola et al. [1], the price of electricity produced in Germany is even the most important factor influencing the EUA price. According to Hammoudeh et al. [12], a positive influence of electricity on the CO₂ emission allowances price can only be assumed if the CO₂ emission allowances price is high, but in general a negative influence can be assumed.

The following Figure 3 shows the influences of the four energy sources (coal, electricity, Brent and gas) on the EUA price as established in the previous literature.

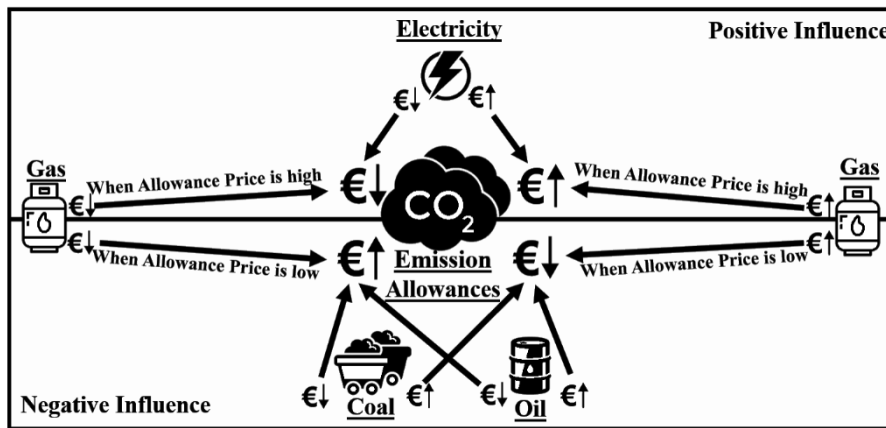


Fig. 3. Influences of energy variables on the price of CO₂ emission allowances.

4 Data and Methodology

4.1 Data

In the present study, working day data from the period 30 September 2013 to 1 October 2019 are taken into account. This covers only phase III of the EU ETS, which started in 2013 and ends in 2020. The time series data were obtained from Thomson Reuters Datastream and contain 1567 observations per variable. Figure 4 shows the development of the observed prices over time. Tables 1 and 2 show basic statistics of the time series before and after the first differences were calculated. The correlation matrix on the basis of the first differences in Table 3 shows consistently positive correlations with mostly high significance.

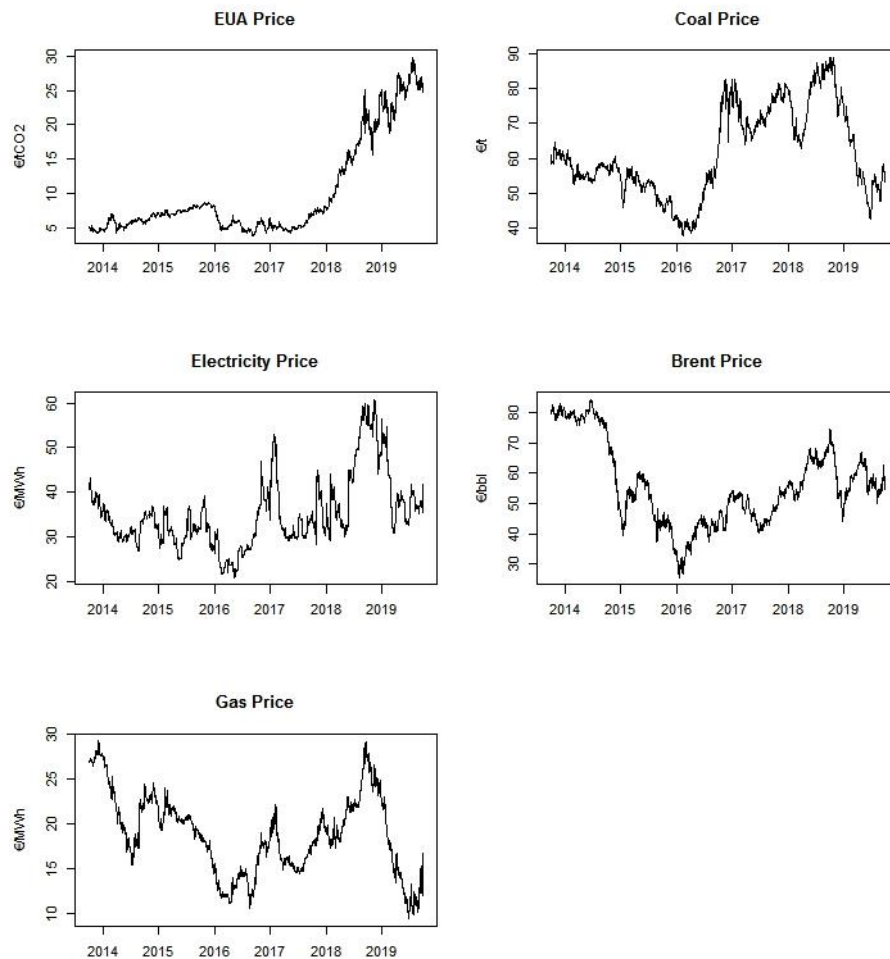


Fig 4. Time series diagrams.

Table 1. Basic statistics on the sample.

Variable	Mean	Median	Standard deviation	Minimum	Maximum
EUA	10.09	6.98	7.03	3.91	29.76
Electricity	35.24	33.42	8.01	20.96	60.84
Gas	18.75	18.64	4.44	9.38	29.29
Coal	61.59	57.95	12.78	37.76	88.90
Brent	56.59	53.87	13.59	25.56	84.49

Table 2. Basic statistics after formation of the first differences.

Variable	Mean	Median	Standard deviation	Minimum	Maximum
d_EUA	0.012784	0.010000	0.348067	-4.050000	2.020000
d_Electricity	0.000013	-0.010000	1.094508	-5.600000	14.070000
d_Gas	-0.006576	-0.020000	0.408956	-2.108000	4.453000
d_Coal	-0.003704	0.019540	0.940489	-7.448123	7.101688
d_Brent	-0.016202	-0.001733	1.048310	-4.778968	8.297314

Table 3. Correlation matrix with significance levels for all variables.

	EUA	Electricity	Gas	Coal	Brent
EUA	1	0.1029***	0.3045***	0.0792**	0.1187***
Electricity	0.1029***	1	0.2405***	0.0774**	0.0556*
Gas	0.3045***	0.2405***	1	0.2728***	0.1461***
Coal	0.0792**	0.0774**	0.2728***	1	0.1539***
Brent	0.1187***	0.0556*	0.1461***	0.1539***	1

Signif. codes: '***' 0.001; '**' 0.01; '*' 0.05; '.' 0.1; ' ' 1

The daily spot prices (in €/t) of the European Energy Exchange (EEX) are used for the price of EUA. For the electricity prices, no intraday or day-ahead prices are considered, but daily closing prices of the next due futures contracts, in order to allow a more precise analysis of the prices in consideration of changes in industrial expectations.

For the oil price (in \$/barrel), the prices of Brent crude oil were evaluated. The corresponding contracts are traded on the ICE Futures, the largest futures exchange for such futures in Europe. The price for coal (in \$/t) is the currently traded contract month on the ICE Futures. It is referenced to the coal index API#2(ARA), which is published in Argus/McCloskey's Coal Price Index Report.

To ensure that all data are in the same currency, the oil and coal rates are converted into euros using the daily reference rates of the European Central Bank.

The gas price (in €/MWh) used for the analysis is the natural gas month-ahead future of the ICE Endex, the largest and most liquid gas exchange in Europe. The electricity price (in €/MWh) is the Physical Electricity Index (Phelix) future price on the EEX for the current month, shown as a Phelix baseload. This refers to the electricity base load and serves as the reference price for electricity in Germany. In this paper, the German

electricity price is used because Germany is the largest economy in the EU and has the highest share of the Europe-wide auction volume among the member states [11].

The original series and the time series after the formation of the first differences, therefore prefixed with "d_...", are tested for stationarity using the Augmented Dickey-Fuller-Test. The results of the test show that none of the original time series exhibit the property of stationarity. The first differences of the time series are all stationary, which is why they were used for the test.

The basis of VAR is that the individual time series in the system influence each other. The Granger causality test is therefore used to test the relationships of the individual variables to each other before the VAR model is created. The p-values of the test show that the prices of fuels (gas, coal and Brent) have a significant influence on the EUA price. No influences of the EUA price on the four energy variables are found. The gas price also shows highly significant influence on the coal price. This justifies the VAR modelling approach for this system with several time series to be forecasted.

Table 4. Pairwise Granger causality tests with a lag of 4.

Null hypothesis	F-statistics	p-value	
Electricity does not Granger cause EUA	1.1454	0.33340	
EUA does not Granger cause Electricity	0.4856	0.74640	
Gas does not Granger cause EUA	2.8012	0.02470	*
EUA does not Granger cause Gas	0.8957	0.46570	
Coal does not Granger cause EUA	2.8933	0.02114	*
EUA does not Granger cause Coal	0.5489	0.69980	
Brent does not Granger cause EUA	5.4137	2.50E-04	***
EUA does not Granger cause Brent	1.0057	0.40330	
Electricity does not Granger cause Gas	0.3437	0.84850	
Gas does not Granger cause Electricity	4.5698	0.00114	**
Electricity does not Granger cause Coal	0.1891	0.94420	
Coal does not Granger cause Electricity	1.5844	0.17590	
Electricity does not Granger cause Brent	1.5995	0.17190	
Brent does not Granger cause Electricity	0.4453	0.77590	
Gas does not Granger cause Coal	7.3872	6.83E-06	***
Coal does not Granger cause Gas	0.5705	0.68410	
Gas does not Granger cause Brent	0.3264	0.86040	
Brent does not Granger cause Gas	1.7755	0.13120	
Coal does not Granger cause Brent	2.3207	0.05489	.
Brent does not Granger cause Coal	0.3906	0.81550	

Signif. codes: '***' 0.001; '**' 0.01; '*' 0.05; '.' 0.1; ' ' 1

4.2 Methodology

In order to model the interactions between the EUA price and energy prices, a VAR model is used for the econometric analysis in this study. In contrast to conventional autoregressive models, this type of time series analysis model does not assume a unidirectional relationship, i.e. that the target variable is influenced by the influencing variables, but not vice versa. In the following VAR model, therefore, the feedback relationships of all variables to be investigated are taken into account; formally expressed, all variables are treated as endogenous:

$$\begin{pmatrix} d_EUA \\ d_Electricity \\ d_Gas \\ d_Coal \\ d_Brent \end{pmatrix} = \mathbf{c} + \boldsymbol{\beta}_{t-1} \times \begin{pmatrix} d_EUA_{t-1} \\ d_Electricity_{t-1} \\ d_Gas_{t-1} \\ d_Coal_{t-1} \\ d_Brent_{t-1} \end{pmatrix} + \boldsymbol{\beta}_{t-2} \times \begin{pmatrix} d_EUA_{t-2} \\ d_Electricity_{t-2} \\ d_Gas_{t-2} \\ d_Coal_{t-2} \\ d_Brent_{t-2} \end{pmatrix} + \dots + \mathbf{u} \quad (1)$$

Where \mathbf{c} is the column vector of the regression constants, $\boldsymbol{\beta}_{(t-n)}$ is the 5x5 matrices of the regression coefficients with lag n and \mathbf{u} is the residuals of the VAR model. Before estimating the model, it has to be determined how many lags should be included. Here it is important to weigh up the pros and cons, because too few lag values may leave valuable information of the more distant values unnoticed or explanatory parameters may be missing, while too many lag values may lead to over-specification of the model. The model includes four lags, based on the Akaike information criterion.

Impulse response functions (IRF) are derived from the VAR model, which indicate how changes in one variable affect other variables. For this purpose, the variables under investigation are subjected to an isolated shock (impulse) in the amount of one standard deviation and its effects over time are determined. For the analysis of the IRF their plots including the bootstrap confidence intervals are used. If the 95% confidence level at a given time includes the zero line, there is no significant effect.

5 Results and Discussion

Figure 5 shows the impulse-response functions and Figure 6 shows the cumulative impulse-response functions of the energy prices under consideration: Brent (crude oil), natural gas, coal and electricity. These functions show the reactions of the EUA price to an impulse from a standard deviation of each energy price.

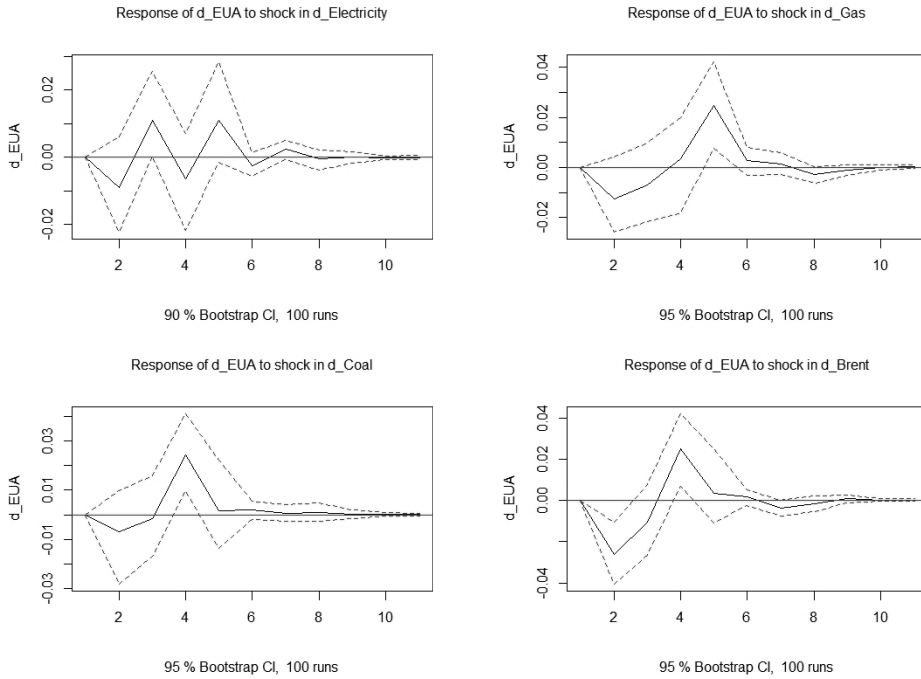


Fig. 5. Excerpts of the impulse response function plots from the 4-Lag VAR-Model.

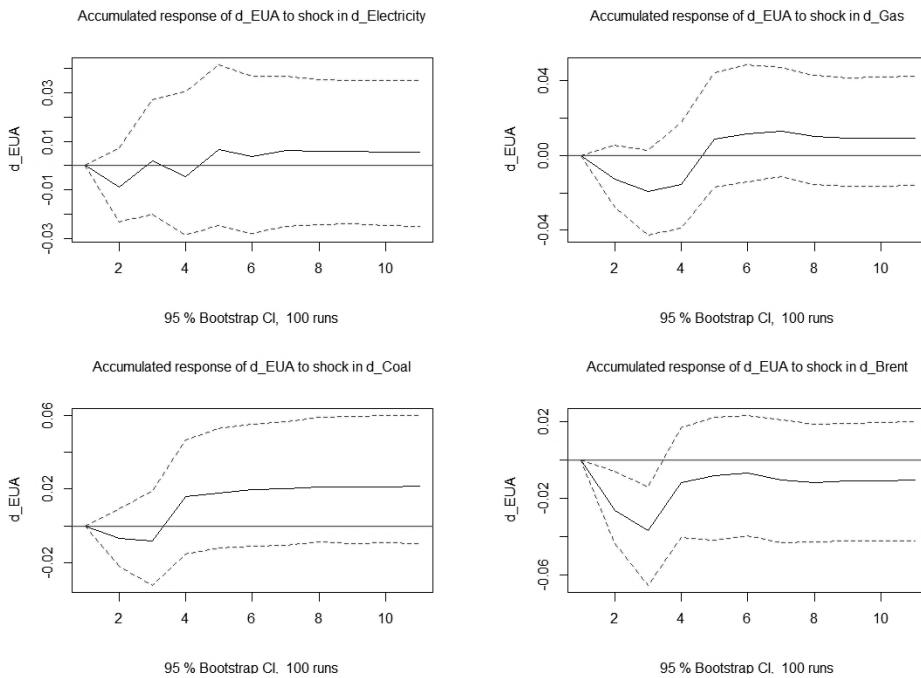


Fig. 6. Excerpts of the accumulated impulse response function plots from the 4-Lag VAR-Model.

The impulse-response function from the EUA price by entering a gas standard normal distribution leads to a decrease of the EUA price after one day. This is followed by a stronger increase in the price. Cumulated, a positive influence can be determined. This correlation between natural gas prices and EUAs could be due to the fact that there is a high degree of substitutability between coal and gas in electricity production. Rising prices in the gas sector therefore lead to a stronger demand for coal. Since a coal-fired power plant for the generation of one kilowatt hour of electricity emits almost twice as much carbon dioxide as a gas-fired power plant, this leads to a rising demand for CO₂ emission allowances and thus to a price increase [14].

The EUA price shows high volatility when the electricity price is stimulated. Overall, an increase in the electricity price leads to a marginal increase in the EUA price. This reaction can be explained by the fact that the companies need electricity for production and a marginal change in the electricity price does not immediately lead to a reaction on the part of the companies, which ultimately leaves the EUA price virtually unaffected. In addition, the electricity price is influenced by production-related factors, especially by the impact of coal and gas prices, so that these two energy prices already absorb the influence of the electricity price on the EUA price [15].

In the event of a shock in the coal price, the impulse response function shows an overall positive correlation with the EUA price. In this way, an impulse in the coal price after one day initially leads to a decline and from day three to a relatively strong increase in EUA prices. This reaction can be explained by the substitutability of coal and gas as described above. Thus, an increase in coal prices could *ceteris paribus* lead to a fuel switch from coal-fired power plants to gas-fired power plants. As a result, emissions will decrease and with it the demand for and price of CO₂ emission allowances. The reaction that the price of EUA rises despite this can be explained by the fact that particularly energy-intensive industries are using this situation to expand their production [10], which means that more electricity is produced by gas-fired power plants, which in turn increases the price of EUAs.

The impulse-response function for the EUAs price shows a negative correlation on the first day in the event of a shock in crude oil, which, with a weaker positive reaction, ultimately leads to a lower EUA price. This reaction can be due to a decreasing demand for crude oil, which is why emissions are lower and therefore the decreasing demand for EUAs leads to a lower price.

The impulse response functions were described and explained in the previous section. In the following, the results are assessed according to their significance, the significance level being used as a measure. The regression parameters of the estimated model with respect to d_EUA are presented in Table 5.

Table 5. Estimation results for equation d_EUA :

	Estimate	Std. Error	t value	Pr(> t)
$d_EUA.I1$	0.0393667	0.0267497	1.472	0.14131
$d_EUA.I2$	0.0207154	0.0268060	0.773	0.43977
$d_EUA.I3$	-0.0705162	0.0268289	-2.628	0.00866 **
$d_EUA.I4$	-0.0685827	0.0267998	-2.559	0.01059 *

d_Electricity.11	-0.0052224	0.0083499	-0.625	0.53178	
d_Electricity.12	0.0118200	0.0083570	1.414	0.15745	
d_Electricity.13	-0.0087327	0.0083586	-1.045	0.29630	
d_Electricity.14	0.0054170	0.0083522	0.649	0.51671	
d_Gas.11	-0.0228549	0.0239048	-0.956	0.33918	
d_Gas.12	-0.0089361	0.0254117	-0.352	0.72515	
d_Gas.13	-0.0154623	0.0253897	-0.609	0.54262	
d_Gas.14	0.0531368	0.0254377	2.089	0.03688	*
d_Coal.11	-0.0041975	0.0098785	-0.425	0.67096	
d_Coal.12	0.0006287	0.0098928	0.064	0.94934	
d_Coal.13	0.0259646	0.0098904	2.625	0.00874	**
d_Coal.14	0.0009338	0.0098027	0.095	0.92412	
d_Brent.11	-0.0255580	0.0085772	-2.980	0.00293	**
d_Brent.12	-0.0116378	0.0086117	-1.351	0.17677	
d_Brent.13	0.0237124	0.0086044	2.756	0.00592	**
d_Brent.14	0.0026161	0.0086028	0.304	0.76109	
const	0.0138457	0.0087713	1.579	0.11465	

Signif. codes: 0; '***' 0.001; '**' 0.01; '*' 0.05; '.' 0.1; ''

Residual standard error: 0.3447 on 1541 degrees of freedom

Multiple R squared: 0.03404,

F-statistic: 2.715 on 20 and 1541 DF, p-value: 6.466e-05

A special focus in this presentation is on the differentiation between significant and non-significant values. The coefficients for Brent (crude oil) show a significant value on the first and third day. The significance level is below 1%. The absolute value of the negative coefficient is marginally higher in comparison and provides a point of reference for forecasting the future development of the EUA price. According to Ham-moudeh et al. [12], an increase in the price of crude oil leads to a sharp decline in CO₂ emission allowances prices and this reaction reflects the present result of the vector autoregression analysis carried out, according to which H1 of this study can also be confirmed in phase III of the EU ETS.

The coal price shows a positive influence on the EUA price on the third day with a significance level of less than 1%. Consequently, the assumed negative influence of the coal price in the context of H2 is not confirmed. As described above, the reasons for this counterintuitive result could be the high degree of substitutability between coal and gas.

The reciprocity between the price of natural gas and the price of EUAs shows a significantly positive influence on the fourth day, as assumed in H3, which has also already been determined by Alberola et al [2].

For the influence of d_Electricity no significant coefficients are found. Therefore, in the present model, in contrast to the existing literature (H4), no correlation between the electricity price and the price of emission allowances can be established. This result can be explained by the fact that the energy prices of coal and natural gas implicitly reflect

the influence of electricity anyway, since these are used for electricity generation, among other things.

6 Conclusion

The results of this work show that the price of EUAs is significantly influenced by the prices of fuels (Brent, coal, gas) in the third phase of the EU ETS. The extent of the influence is less pronounced for the individual energy variables than was observed in the previous phases. Furthermore, the influence of the electricity price on the EUA price cannot be determined in the third phase. While the negative influence of Brent and the positive influence of gas are confirmed, a positive influence on the EUA price is observed for coal, contrary to the existing literature. This shows that the market influences in phase III of the EU ETS have changed compared to the previous phases. One reason for this may be that fossil fuels are gradually being pushed out of the energy market by renewable energies. Electricity can also be produced with much lower emissions than it was the case in the first phases of the EU ETS. The influence of the individual energy sources on the EUA price has fallen accordingly over time. The present results could therefore be an indication that the pricing of EUAs as an EU instrument is no longer effective. The tendency for EUA prices to rise also indicates that this effect will continue to increase in the coming years and that even lower-emission technologies will be focused on the European area.

Accordingly, this work offers the opportunity for further research to investigate the forecasting capabilities of the EUA, taking into account other factors such as weather or economic activity in the EU.

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The General Dynamic Market Model and Software Application for Support Modeling Process

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Abstract. Economics has entered the stage of deep transformation of its bases. The traditional method of constructing a scientific theory is first to synthesize and investigate mathematical framework; this traditional approach was taken as a principle of our research. Finally the mathematical theory of the general dynamic market model has recently been constructed, the main elements of which are given in this paper. The next step is to build models of specific real markets based on the general theory. The C# application *Model* was created especially to support the synthesis of concrete models based on the general theory. The most important goal of this paper is to propose cooperation in such research.

Results of the research: the crucial factors, which ensure the market stability, are the market coherence and the market intention to adaptive expectations. If no any firm uses naive expectations in the market then with sufficiently small incoherence there is unique Nash equilibrium, which is stable for all acceptable values of parameters. The increase of naive expectations leads to stability loss, to flip bifurcations and finally to chaos. The increase of number of firms also as a rule leads to stability loss and finally to chaos. At sufficiently small changes in production per step, systems of general dynamic market model turns into systems of neoclassical microeconomics.

Keywords: modeling, computer simulation, C# desktop application, dynamic, economics, general market model, adaptive expectations.

1 Introduction

Increasingly, processes and systems are researched or developed through computer simulations and this trend is likely to continue [1]. Information technology in the economy made it possible to model artificial societies and study economic models through the computer simulation [2]. Economics has entered the stage of deep transformation of its bases. In recent years the researchers are renouncing the assumption of perfect rationality as unconditional basis of economic agents' behavior [3], [4].

The real economic processes make a clear demonstration that neoclassical "rational man" is not their subject. In real economy "optimal imperfect decisions" are taken by simple and non-expensive calculations, well adapted to frequent repetitions, to

evolution [5]. All it means that the real economy is dynamical system, and real processes of economy are iterative processes of this system.

Now institutional school of economics analyzes economic systems as a result of evolutionary process of participants' interaction [6]. New paradigm of economics is a mix of the nonlinear dynamical system theory and mathematical programming, including game theory and optimal control theory [7]. And the main tool of new economics is simulation modeling grounded on the basis of 3 computer paradigms (object-oriented, dynamic and multi-agent system) [8].

Modern development of dynamic paradigm in economics is a wide stream of researches. However it is a stream of examples which are not developing in the general theory; their relations with real markets are often problematic [9]. The traditional method of constructing a scientific theory is first to synthesize and investigate mathematical framework – the general market model according to the new dynamic paradigm of economics. And then we can study complex real systems which are grounded on this basis. This traditional approach was taken as a principle of our research.

Indeed, the idea of this research arose in the course of computational experiments with the two-dimensional market model [10], [11], its particular case, which became the foundation of the general theory. The general market model was synthesized in [12]. A computational study of the model was demonstrated there, and on this basis some hypotheses about the general theory, formalizing the calculation results, were formulated. Finally, the mathematical theory of the general dynamic market model has recently been constructed, the main elements of which are given in this paper.

The next step is to build models of specific real markets based on the general theory. In this direction, we have just started: we explored the Australian retailer market, based on the general market model. For this purpose Data Republic technologies were used, which provided comprehensive initial data for research, as well as new methods of machine learning [13]. But hardly such a task can be realized by one person. The most important goal of this paper is to propose cooperation in future research. For this purpose, we offer not only the general market theory, but also a specialized software application. The C# application *Model* was created especially to support the synthesis of concrete models based on the general theory. To date, we are not aware of applications created for such purpose.

Generally speaking, computational modeling derives from two steps: (i) modeling, i.e. finding a model description of a real system, and (ii) solving the resulting model equations using computational methods. In the natural sciences it is often not so difficult to find a suitable model, however the resulting equations tend to be very difficult to solve, and can in most cases not be solved analytically at all [14], [15]. On the other hand, in subjects that are not as well described through a mathematical framework and depend on behavior of objects whose actions are impossible to predict deterministically (such as humans), it is much more difficult to find a good model to describe reality [16], [17], [18]. As a rule, in these disciplines (such as economics) the resulting equations are easier to solve, but they are harder to find and the validity of a model needs to be questioned much more [19]. Therefore, in these applications it turns out to be expedient and convenient to use a computer already at the stage of synthesizing the model. It is such desktop *Model* is proposed in this paper.

The **paper goal** is to introduce the general dynamic market model; to introduce the specialized C# application *Model* and to demonstrate the use of the *Model* in building the general market model; the most important goal is to propose cooperation in future research.

The paper is organized as follows: in part 2 we introduce the general dynamic market model; in part 3 we demonstrate desktop application *Model*; part 4 concludes.

We had to omit proofs of propositions in order to fit the paper format.

2 General Market Model

2.1 Main definitions

First of all let's introduce the basic concepts of the model. We consider a market of homogeneous product, where exogenous parameter $n(t)$ indicates how many firms operate at time t . Each firm produces output $x_i(t)$, where $i = 1, \dots, n(t)$. Thus the industry output of the market is $Q(t) = \sum_{i=1}^n x_i(t)$ at time t . Product price $P(t)$ is given by isoelastic demand function $P(t) = b(t)/Q(t)$ ($b(t) > 0$).

Formally the firm is defined by its objective function. Firm maximizes both its own profit $\pi_x = (P - v) \cdot x - fc$, where $v = v(t)$ is the firm's competitive marginal cost per unit in the market, $fc = fc_i(t)$ is fixed cost, and consumer surplus $CS = CS_i(t)$ is a difference between maximum price which consumer can pay and real price. Here $CS = \Theta \cdot \left(\int_{\varepsilon}^Q P(q) dq - P \cdot Q \right)$, where parameter ε is the minimal technologically possible product quantity, $\Theta = \Theta_i(t)$ specifies the segment of the market, which the firm believes its own and optimizes; usually $\Theta_i(t) = \frac{\gamma_i(t)}{n(t)}$, where $\gamma_i(t)$ is the given model parameter. Then

$$CS = \Theta \cdot \left(b \cdot \ln \left(\frac{Q}{\delta} \right) - \frac{b}{Q} \cdot Q \right) = b \Theta \cdot \left(\ln \left(\frac{Q}{\delta} \right) - 1 \right) = b \Theta \cdot \ln \frac{Q}{\delta} \quad ,$$

where $\bar{\delta} = \delta \cdot e$ (specific choice of δ does not affect the model dynamics and so further we suppose $\bar{\delta} = 1$). Then general profit function $\Pi = \Pi_i(t)$ ($i = 1, \dots, n(t)$) of firm is:

$$\Pi = \alpha \pi + \beta \cdot CS = \alpha \cdot ((P - v)x - fc) + \beta \cdot b \Theta \cdot \ln \frac{Q}{\delta} \quad ,$$

where $\alpha = \alpha_i(t)$ is share of short-run own profit $\pi = \pi_i(t)$ in the objective function, $\beta = \beta_i(t) = 1 - \alpha$ is share of consumer surplus CS , $fc = fc_i(t)$ is a fixed

cost. As a matter of fact Π is the weighted average of short-run profit π and expected stable long-run profit.

Adaptive planning

The methods used by firms for planning are extremely diverse and hardly a general uniform description of them is possible in principle. Here, in the General dynamic market model, we use only one obvious and universal consideration. If firms i and j are identical at moment t and in particular they have the same planning at moment t , then it is natural for firm when planning to suppose that their production quantities will be equal at next moment $t+1$ too.

In most general case for mixed naïve and adaptive expectations

$$x_{ij}^e(t+1) = \delta_{ij}(t)x_i(t+1) + \chi_{ij}(t)x_j(t) \quad (0 \leq \delta_{ij}(t) \leq r_{ij}(t), \chi_{ij}(t) = (1 - p_{ij}) + (r_{ij}(t) - \delta_{ij}(t)) \geq 0). \quad (1)$$

Here $\delta_{ii}(t) \equiv 1$, $\chi_{ii}(t) \equiv 0$ for all i and t . Thus according to (1) prospective industry output of a market expected by a firm i during next time period $t+1$ is equal to

$$Q_i^e(t+1) = \sum_{j=1}^{n(t)} x_{ij}^e(t+1) = \sum_{j=1}^{n(t)} \delta_{ij}(t) \cdot x_i(t+1) + \sum_{j=1}^{n(t)} \chi_{ij}(t)x_j(t) \quad (2)$$

Then under planning of their quantity $x_i(t+1)$ in next period $t+1$ each firm i maximizes objective function Π_i^e $i = 1, \dots, n(t)$. Thus we obtain the equations of dynamics of the general market model [12]

$$c_i x_i(t+1) = \sqrt{\frac{b}{v}} w_i(t) + d_i^2 + d_i - w_i(t) \quad (i = 1, \dots, n(t)), \quad (3)$$

$$\text{where } c_i = c_i(t) = \sum_{j=1}^{n(t)} \delta_{ij}(t), \quad w_i(t) = \sum_{j=1}^{n(t)} \chi_{ij}(t)x_j(t), \quad d_i = d_i(t) = \frac{1}{2} \frac{b\Theta_i}{v} \frac{\beta_i}{\alpha_i} c_i(t).$$

In this paper we consider all actions, expectations and strategies of firms in short-run time period Δ , therefore the equations parameters n , c_i , d_i , δ_{ij} , χ_{ij} etc. are assumed further as constants which are independent of time.

2.2 Main propositions of the theory

Let's define the key notion of *market coherence* in the general market model. Let $x_{ik}^e(t+1)$ is quantity of output of firm k expected by a firm i ,

$Q_i^e(t+1) = \sum_{k=1}^n x_{ik}^e(t+1)$ is prospective industry output of a market expected by a

firm i during next time period $t+1$ from (2). Then for firms i and j we put

$$\varepsilon_{ij} = \max_{t \in \Delta} \frac{|Q_i^e(t+1) - Q_j^e(t+1)|}{Q(t)}, \text{ where } Q(t) \text{ is industry output of the market in period}$$

t , Δ is the time period considered. Value ε_{ij} characterizes *incoherence* in expectations of firms i and j . Therefore value $\varepsilon = \max_{i,j} \varepsilon_{ij}$ we will call the level of

incoherence of market expectations or simply the *market incoherence*. Finally, the value $1 - \varepsilon$ we will call the level of coherence of market expectations or simply the *market coherence*.

$$\text{Let } P = \min_{t \in \Delta} P(t), \quad \Theta = \max_i \Theta_i, \quad B = 4 \frac{v}{P} n, \quad D = 2\Theta n, \quad \beta = \max_i \frac{\beta_i}{1 - \beta_i},$$

$$c_i = \sum_{k=1}^n \delta_{ik}, \quad C_{ij} = \frac{c_i}{c_j}, \quad \lambda_{ij}(t) = \frac{x_i(t)}{x_j(t)}, \quad \text{where } i, j = 1, \dots, n.$$

Proposition 1. (Main lemma) Let $2Q(t) > Q_i^e(t)$ for all $i = 1, \dots, n$, $t \in \Delta$ and j be the number of a firm with a production volume $x_j(t)$ above the average:

$$x_j(t) \geq \frac{\sum_{k=1}^n x_k(t)}{n} = \frac{Q(t)}{n} \quad (t \in \Delta).$$

Then for sufficiently small β , for all $i = 1, \dots, n$ and all $t \in \Delta$

$$|\lambda_{ij}(t) - C_{ij}(1 \pm D\beta)| \leq B\varepsilon.$$

Let's define the second key notion in the general market model. According to (1), the higher intention of a firm to plan with adaptive expectations the closer δ_{ij} to r_{ij} . So in the notations (1) the value

$$\Lambda = \frac{\sum_{i,j=1(i \neq j)}^n \delta_{ij} x_j}{\sum_{i,j=1(i \neq j)}^n r_{ij} x_j} \quad (0 \leq \Lambda \leq 1)$$

we will call the intention to plan with adaptive expectations in the market or simply the *market intention to adaptive expectations*.

Proposition 2. At $\Lambda = 1$ with all sufficiently small ε and β there is the unique Nash equilibrium for the dynamic system (3) and this equilibrium point is stable for all admissible values of the parameters.

Proposition 3. At $\Lambda = 0$ with all sufficiently small ε and β there is the unique Nash equilibrium and this equilibrium point is unstable and hyperbolic for all admissible values of the parameters of the almost any dynamic system (3).

But what is the behavior of system (3) for $0 < \Lambda < 1$?

Proposition 4. For dynamic system (3) with all sufficiently small ε and β with decrease in Λ from 1 to 0 flip bifurcations (cycle doubling bifurcations) occur throughout the Sharkovskii's order and finally the state of dynamic chaos arises.

This proposition, unlike the previous ones, even formally uses the results of computational studies of dynamics of the two-dimensional market models. For such application computations through *Model* were carried out.

Proposition 5. For dynamic system (3) there is such a segment $[a; b]$ ($0 < a < b < 1$), that for all $\Lambda \in [a; b]$, with all sufficiently small ε and β , with increasing n flip bifurcations (cycle doubling bifurcations) occur throughout the Sharkovskii's order and finally the state of dynamic chaos arises.

Proposition 6. For sufficiently small $x_i(t+1) - x_i(t)$ and respectively small β_i ($i=1, \dots, n, t \in \Delta$) the dynamics of system (3) has the unique stable Nash equilibrium point with an equilibrium price in the market.

Proposition 6 means fulfilling the premises of classical economic theory at sufficiently small changes in production per step. Speaking informally, at sufficiently small changes in production per step, systems of general dynamic market model turns into systems of neoclassical microeconomics.

3. Desktop Application for Support Modeling Process

C# application *Model* created to support the modeling process. Its main goal is to maximize research support, to provide the best service for a regular cycle: hypothesis \rightarrow experiment \rightarrow hypothesis. The basic requirements implemented in the specialized software application are i) obtain a model in the subject language without codes; ii) immediately obtain all the necessary research tools already configured for this model; and most importantly, iii) it is easy to modify the model depending on the results of computer experiments. The main requirement is that new ideas should immediately be put into experiments for verification. In natural experiments it is impossible to immediately implement a new idea, immediately creating a new device. But in *Model* with computer simulations we can do this using the program window with the appropriate tools: new experiment results create new ideas that we test immediately by creating appropriate new windows.

The following figure shows the main program window, which automatically appears when you open the *Model*.

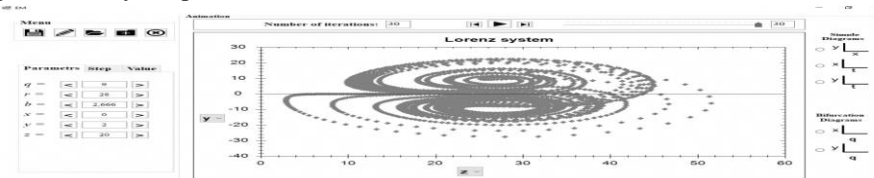


Fig. 1. *Model's* main window

But the main tool to support the synthesis of concrete models using the *Model* is a simple modification of the current model. After pressing the second menu button (the "Edit" button) we get the window of fig. 8.

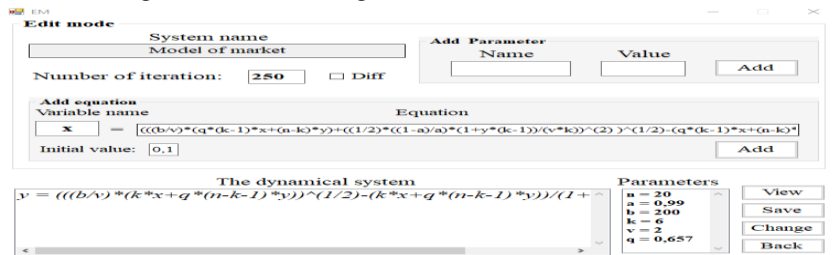


Fig. 2. Window for setting or modifying a dynamic system

The editing window on the screen is located above the current model window, which allows both windows to be used simultaneously. Left-click on the model equation in *The dynamical system* field to go to the *Equation field*, where you can change it. After clicking the *Add button* the modified equation is written back to *The dynamical system* field. Similarly, such a procedure can be performed with parameters in the *Add Parameter* field.

3 Conclusion

Economics has entered the stage of deep transformation of its bases. The traditional method of constructing a scientific theory is first to synthesize and investigate mathematical framework – the general market model according to the new dynamic paradigm of economics. And then we can study complex real systems which are grounded on this basis. This traditional approach was taken as a principle of our research.

The mathematical theory of the general dynamic market model has recently been constructed, the main elements of which are given in this paper. We show that the definition of our model really consists only of simple and obvious constructions; that there is nothing in it that would not inevitably enter into the model of any market of homogeneous products.

Dynamics of the general market model with sufficiently small *incoherence* in the market is stratified on dynamics of two-dimensional markets. The main lemma of theory allows us to generalize properties of simple two-dimensional market models by means of formal reduction to the general market model of this paper.

The crucial factors which ensure the market stability are the *market coherence* and the *market intention to adaptive expectations*. If no any firm uses naive expectations in the market then with sufficiently small *incoherence* there is unique Nash equilibrium which is stable for all acceptable values of parameters. The increase of naive expectations leads to stability loss, to flip bifurcations and finally to chaos.

The increase of number of firms as a rule also leads to stability loss, to bifurcations and finally to chaos in the market. Thus behavior of general view markets is sharply different from their usual behavior in neoclassical microeconomic theory. However at sufficiently small changes in production per step, systems of general dynamic market model turns into systems of neoclassical microeconomics. This means that general dynamic theory does not contradict logically the neoclassical static theory, despite their striking unlikeness.

The next step is to build models of specific real markets based on the general theory. The C# application *Model* was created especially to support the synthesis of concrete models based on the general theory. To date, we are not aware of applications created for this purpose. The most important goal of this paper is to propose cooperation in such researches.

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Mathematical-Logistic Model of Integrated Production Structure of Food Production

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Abstract. The article is devoted to the formation of a technological-logistic model of the integrated structure of food production. The main goal of corporate structure management is the integration of all its constituent units for the fulfillment of the mission, which ensures achievement of the set goals. The main purpose of modeling is to show how the intermediate links-enterprises are logically formed the target object. A mathematical formulation of the problem of choosing optimal capacities and rational location of enterprises, as well as minimum costs for transportation of raw materials, is proposed. A complex mathematical model for planning the production of agricultural raw materials and processing it into ready-made food products in the system "agricultural sector - provision / primary processing - food industry enterprises" was formed. Model of the logistic organization of integrated food production are based on the principles of rational organization of the technological chain and are characterized by: complexity, universality, differentiation of the approach; specialization. The developed mathematical model allow planning and programming of the development processes of the integrated food production system, assessing the impact of changes in the parameters of the system, and adjusting plans. With the help of Statgraphics, Statistica, Excel software and having as a basis an array of enterprise data, it is possible to plan and program the development processes of an integrated food production system, assess the impact of changes in system parameters, make adjustments to plans. The model make it possible to specify the technological complex of work and the need for raw materials, provide an opportunity to establish boundaries between complexes of works of individual companies and, in general, the responsibility of the entire corporate structure.

Keywords: logistic model, food industry, agrarian sector, integrated production, economic-mathematical modeling

1. Introduction

The food industry is one of the few branches of the Ukrainian economy, which is in the stage of steady development. However, the raw material base of food production – the agricultural sector of Ukraine today is in a crisis condition, characterized by a decline in the material and technical base, high costs of production, shortage of working capital.

Measures to implement integrated development strategy should be scientifically sound and rely on mathematical models of processes that will take place in a new production system.

Technological peculiarities of the production of agrarian products, as well as the complexity of the processes of its harvesting, accumulation and, if necessary, primary processing, processing into finished products, make a relevant mathematical modeling of the planning of production of raw materials, taking into account possible changes in production volumes. The purpose of the article is to study the technological and logistical side of the rational organization of the integrated complex of enterprises "agriculture - procurement organizations - enterprises of the food industry". The objectives of the paper are: the identification of production, economic and transport factors of the interaction of production in the technological chain of food production and the mathematical formulation of the task of choosing the optimal capacities and rational allocation of the integrated production complex enterprises, as well as the minimum costs for the transportation of raw materials.

2. Related Works

It should be noted that the issue of the placement of specialized agricultural enterprises and the transportation of products produced by agrarian enterprises has been given attention in the literature since the 60-s of the last century [1].

The issue of solving problems of optimization of processes in agrarian and processing sectors of the economy of Ukraine and today are at the center of attention.

So in the works of Y. Brodsky [2] and S. Nakonechny [3] shows the economic and mathematical functioning of agrarian enterprises, in particular models of production structure, innovation processes, technical and economic processes. These models have a high level of reliability, however, they cover only the primary link in the technological and logistic chain of food production.

Separately allocated works related to the simulation and optimization of logistics processes in the industry, such as scientific work Y. Borbot [4]. Problems of find optimal solutions in the industrial production and logistics system have been analyzed in articles of modern scientists, like A. Gola [5]. But we can't say about existing of universal optimization model. Individual model of optimization of food production and logistics system of particular kind of food product must consider all set of

specific features of the sector.

It should be emphasized that market requirements today require the formation of a complex integrated system of agro-industrial food production, which will enable to realize the reserves of competitiveness of the industry. Consequently, it is necessary to approach the modeling of technological and logistic processes in a complex way. The necessity of mathematical modeling of the planning of the enterprises of the food industry and its raw material base is caused first of all by the possibility in this case of more rational use of available resources and optimization of commodity-cash flows [6, 7].

Taking into account that the question of modeling the optimal development of the food production complex remains open, we will try to propose an own view on its solution in this paper.

3. Research Methods

The tasks of logistic management of commodity flows in order to minimize costs and maximize profits in the food production system is a complex methodological task, as the technological chain of food production involves a large number of actors that enter into interaction. Consequently, it is necessary to take into account the whole set of participants in production and to coordinate their numerous interactions, taking into account their functional features of their organization and the technology of the work.

To solve this problem we used the instrumental apparatus of mathematical modeling, namely - setting up an optimization problem Z-type with a system of constraints, which allows the most adequately describe the investigated technological and logistic system. During the study was developed the model of optimization of capacities of production units and minimization of expenses for transportation of raw materials. Limitations of the model are the volumes of raw material production, the quantities of raw materials delivered between the stages of the technological process and the volume of raw materials transported between all the links of the production-technological chain. Method of formation and structural composition of the model are shown on the fig. 1.

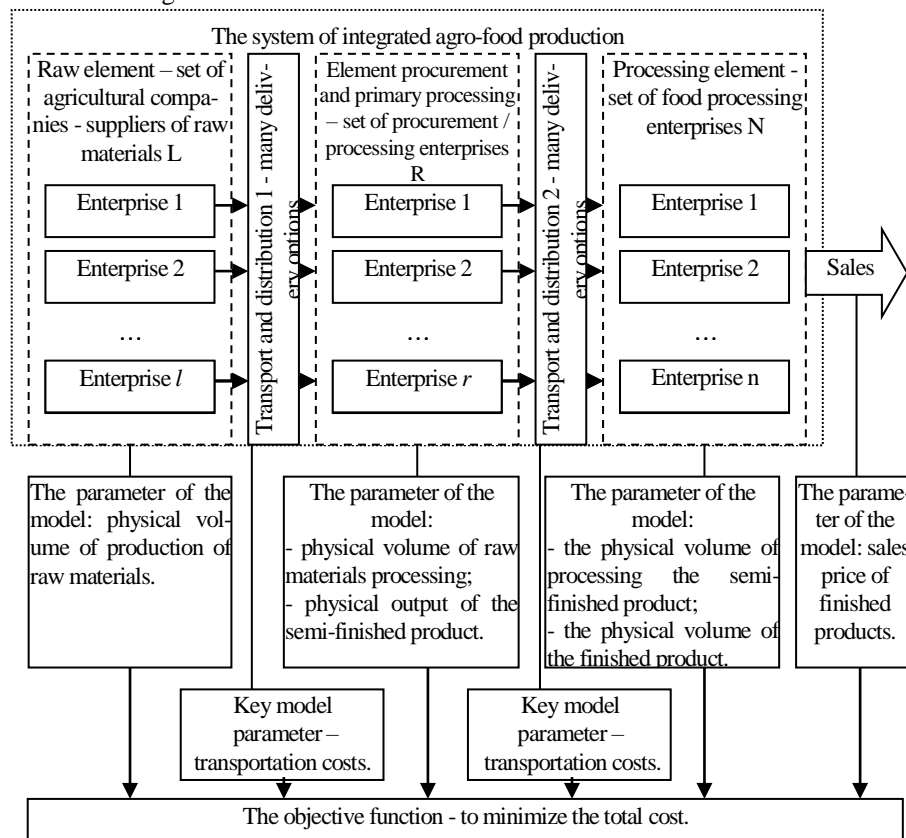


Fig. 1. Component of the model for optimizing production and logistics chains of an integrated agrarian-food production structure

The system should strive to get close to the ideal state of operation, which will ensure the economy of resources and maximize returns.

For the practical use of this model, the formation of an appropriate information environment is required by monitoring and accumulating the statistical base of parameters that characterize the use of resources, costs, production and logistics and transport and logistics flows.

4. The Proposed Optimization Model

In the complex of integrated production, a number of small agricultural enterprises, several harvesting organizations and / or primary processing enterprises, one or several enterprises of the food industry are connected. All of them are, as a rule, geographically located in one region or neighboring regions of Ukraine - in the zone of growing of raw materials. Since each enterprise of the next stage is a consumer of raw materials or semi-finished products produced by enterprises of the previous stages, the desired quantities can be represented in homogeneous units of measurement by means of conversion into a single conditional product.

The mathematical model of the optimal development of the food production complex consists of the objective function $F(x)$, which expresses the general minimum expected costs of growing the raw material, its harvesting and primary processing and transportation of products:

$$F(x) = \sum_{j=1}^n \sum_{k=1}^l C_{jk} x_{jk} + \sum_{j=1}^n \sum_{k=1}^l C^*_{jk} x^*_{jk} + \sum_{j=1}^n \sum_{k=1}^l \sum_{i=1}^r S_{jki} x_{jki} + \sum_{j=1}^n \sum_{k=1}^l \sum_{i=1}^r C_{jki} x_{jki} + \sum_{j=1}^n \sum_{i=1}^r \sum_{m=1}^p S_{jim} x_{jim} \rightarrow \min, (6)$$

where: k is one of the plurality (1,2,3, ..., k , ..., l) of agricultural enterprises producing agrarian raw materials and supplying it to procurement organizations and / or primary processing enterprises; j is one of the plural (1,2,3, ..., j , ..., n) type of raw material produced by the k -th agricultural enterprise; i is one of the plurality (1,2,3, ..., i , ..., r) of procurement organizations and / or primary processing enterprises; m is one of the plural (1,2,3, ..., m , ..., p) enterprises of the food industry, which produces the final product; τ - one of the plural (1,2,3, ..., τ , ..., t) years of the planned period of development of food production; C_{jk} - production costs of the unit of raw material of the j -th species in the k -th agricultural enterprise; C^*_{jk} - costs related to the expansion of the sown area / livestock to obtain an additional unit of raw material of the j -th species in the k -th agricultural enterprise; C_{jki} - expenses for processing of the unit of volume of raw material of the j type, received from the k -th agricultural enterprise at the i -th enterprise of primary processing; S_{jki} - transportation costs per unit of raw material of j -th type from k -th agricultural enterprise to i -th enterprise of primary processing and / or procurement organization; S_{jim} - transportation costs per unit of raw material j -th type from the i -th primary processing enterprise and / or procurement organization to the m -e enterprise of the food industry; v_j - the largest volume of raw materials of the j -th type, which should be developed by all 1

agricultural enterprises; V_j - the largest volume of j -th type raw material, which can be taken for processing from all l agricultural enterprises all r of the enterprise of primary processing; W_j - the largest volume of j -th type raw material, which can be taken for processing by all r of procurement organizations and / or enterprises of primary processing all p enterprises of the food industry; x_{jk} - the desired amount of raw material of the j -th species, which should be developed in the k -th agricultural enterprise; x^*_{jk} - the required additional amount of j -th type raw material to be produced in the k -th agricultural enterprise; x_{jki} is the desired amount of j -th type raw material delivered from the k -th agricultural enterprise to the i -th primary processing enterprise and / or procurement organization; x_{jim} - the required volume of j -th type raw material, delivered from the i -th enterprise of primary processing and / or procurement organization to the m -th enterprise of the food-processing industry; Go_{jk} - quantity (in units of measurement) of j -th type raw material at k -th agricultural enterprise; Gn_{ji} - the need (in units of measurement) of j -th type raw material at the i -th enterprise of primary processing and / or stockpiling organization; Go_{ji} - the quantity (in units of measurement) of j -th type raw material at the i -th enterprise of primary processing and / or procurement organization; Gn_{jm} - demand (in units of measurement) of raw material of the j -th type at the m -th enterprise of the food-processing industry/

Restrictions of model:

1. The gross output of j -type raw material by all l agricultural enterprises must be agreed in advance with all enterprises of primary processing and / or procurement organizations:

$$\sum_{k=1}^l (x_{jk} + x^*_{jk}) \leq V_j; \quad (7)$$

2. The total volume of deliveries of raw materials of the j -th type to all l agricultural enterprises should not exaggerate the possibilities of its processing by all enterprises of primary processing:

$$\sum_{k=1}^l \sum_{i=1}^r x_{jki} \leq V_j; \quad (8)$$

3. The total volume of supplies of j -type raw materials by all enterprises of primary processing and / or procurement organizations should not exaggerate the possibilities for its processing by all enterprises of the food industry:

$$\sum_{i=1}^r \sum_{m=1}^p x_{jim} \leq W_j; \quad (9)$$

In this case, to perform compatibility of the conditions of the problem, it is necessary that there are fair inequalities:

$$v_j \leq V_j \leq W_j. \quad (10)$$

In the set task the criterion of optimality is taken the minimum of production and transport costs. With the closed model of the transport task to the specified restrictions, the following is added:

4. The gross volume of j -type consignments shipped from all l agricultural enterprises should correspond to the total demand for these cargoes at the destination points of each of the r enterprises of primary processing and / or procurement

organizations:

$$\sum_{j=1}^n \sum_{i=1}^r x_{jki} = G^o_{jk}; (11) \quad \sum_{j=1}^n \sum_{k=1}^l x_{jki} = G^h_{ji}; (12) \quad \sum_{k=1}^l G^o_{jk} = \sum_{i=1}^r G^h_{ji} (13)$$

The same value should occur when sending materials to the food industry:

$$\sum_{j=1}^n \sum_{m=1}^p x_{jim} = G^o_{ji}; (14) \quad \sum_{j=1}^n \sum_{i=1}^r x_{jim} = G^h_{jm}; (15) \quad \sum_{i=1}^r G^o_{ji} = \sum_{m=1}^p G^h_{jm}. (16)$$

If the problem under consideration is to be formulated in a dynamic statement, then the mathematical model to be derived should be classified in a particular year, which we accept for the first ($\tau = 1$) in the planned period t . In this case, the target function $Z(x, \tau)$ takes the form:

$$Z(x, \tau) = \sum_{\tau=1}^t F_{\tau}(x) \rightarrow \min, \quad (17)$$

where $F_{\tau}(x)$ means that the parameter τ is present as an additional index for all parameters and variables of the function $F(x)$.

Since the dynamical model implies the need to increase the production plan with each passing year, the relationship must be fulfilled:

$$0 \leq x_{jk\tau} \leq x_{jk(\tau+1)}, \quad 0 \leq x_{jki\tau} \leq x_{jki(\tau+1)}, \quad 0 \leq x_{jim\tau} \leq x_{jim(\tau+1)}. (18)$$

5. Results and discussion

The offered mathematical model allows to carry out planning and programming of processes of development of the new integrated food production system, to estimate influence of changes in system parameters and to make adjustments of plans. The output data for calculating the optimal amount of raw materials for production and processing are given in the table 1.

Table 1. The output data for calculating the optimal amount of raw materials

The raw material base								
Farms	Area under crops, ha	Crop capacity, t/ha	Available amount of raw materials, t	Distribution of raw materials (G_{0jk}), t		Unit production costs (C_{jk}), uah/t	Transportation costs (S_{jki}), UAH/t	
				Kherson	Nash Product		Kherson	Nash Product
1. Chaika	10	70	700	700	-	7000	30	35
2. Lotos	27	60	1620	800	-	6000	25	30
3. Ukraine	20	55	1100	500	-	5000	20	25
4. Druhba	50	40	2000	-	2000	5000	30	24
5. Ahrkom	35	30	1050	-	1000	4000	20	15
Primary processing								
Processing enterprises	Need for raw materials (G_{njk}), t		Output products, t	Unit production costs (C_{ji}), UAH/t		Costs of transportation to the food business (S_{jim}), UAH/t		

1. Kherson	2000	350	11000	15
2. Nash product	3000	500	10000	25
Production of finished products				
Enterprises	Volume of consumed raw materials (G_{nijm}), t	Unit production costs (C_{jim}), UAH/t	Price of the finished product, UAH/t	Total cost $F(x)$, UAH
1. Pani Kristina	850	5000	40000	39431750

A real system of production of tomato raw materials (tomatoes → tomato paste → ketchup), localized on the territory of Belozersky district of the Kherson region, was selected to test the model. The system consists of three production steps. The first stage is the raw material base, which is represented by farms (F) “Chaika”, “Lotos”, “Ukraine”, “Druzhba” and “Ahrokom”, which grow tomatoes. The second stage is the primary processing, which is represented by processing enterprises LLC Fruit and Vegetable Plant “Kherson” and PE “Nash Product”, which produce tomato paste. The third stage is the enterprise of the food industry of PICF "Pani Kristina", which produces the final product - ketchup under the trademark "Holiday".

The calculation of the model was made using the SAS Model Manager software. Results of optimization of the model are presented in the table 2.

Table 2. Calculating the optimal amount of raw materials

The raw material base								
Farms	Area under crops, ha	Crop capacity, t/ha	Available amount of raw materials, t	Distribution of raw materials (G_{0jk}), t		Unit production costs (C_{jk}), uah/t	Transportation costs (S_{jki}), UAH /t	
				Kherson	Nash Product		Kherson	Nash Product
1. Chaika	10	70	700	-	-	7000	30	35
2. Lotos	27	60	1620	850	-	6000	25	30
3. Ukraine	20	55	1100	1100	-	5000	20	25
4. Druzhba	50	40	2000	50	1950	5000	30	24
5. Ahrokom	35	30	1050	-	1050	4000	20	15
Primary processing								
Processing enterprises	Need for raw materials (G_{njk}), t	Output products, t	Unit production costs (C_{ji}), UAH/t	Costs of transportation to the food business (S_{jim}), UAH/t				
1. Kherson	2000	350	11000	15				
2. Nash Product	3000	500	10000	25				
Production of finished products								
Enterprises	Volume of consumed raw materials (G_{nijm}), t	Unit production costs (C_{jim}), UAH/t	Price of the finished product, UAH/t	Total cost $F(x)$, UAH				
1. Pani Kristina	850	5000	40000	38025050				

According to the results of the calculation, optimal volumes of production and supply of raw materials and semi-finished products in the technological chain of

production and processing of tomatoes were determined. In the basic, actually existing (non-optimal) version of production, the total amount of expenses is 39431750 UAH, the optimal amount of expenditures is $F(x) = 38025050$. The obtained data allow to reduce expenses for production and transportation of products, increase production efficiency. In particular, the cost saving is 1406700 UAH.

It is possible to recommend "Chaika" to refuse to produce raw materials in favor of other types of products, due to economic impracticability. It is recommended to reduce volumes of tomato crop area for Lotus, and it is advisable to revise programs for the supply of raw materials to processing plants. In particular, the part of raw materials from "Druzhba" should be sent to the processing plant LLC Fruit and Vegetable Complex "Kherson".

6. Conclusions and Outlook

The construction of a cost management system in integrated food production should be based on the principle of feedback, that is, on the needs of food industry enterprises, which are conditioned by the market conditions. The resource management cycle, like the whole system of control of the technological chain, should cover all stages of product creation.

The offered model of the technological-logistic integrated structure of food production should be used in practice in the activity of the enterprise of the food sector.

With the help of Statgraphics, Statistica, Excel software, and based on the enterprise data array, it is possible to plan and program the development processes of the integrated food production system, to evaluate the impact of changes in the parameters of the system, to make adjustments to the plans.

These programs are most user-friendly for beginners due to the lack of targeting a specific subject area, a wide range of statistical techniques, and a user-friendly interface. They are more accessible to practice and can be used by a wide range of specialists of different profiles.

Using the proposed model will significantly reduce the need for raw materials in the enterprise. In addition, a significant reduction in the likelihood of errors when making managerial decisions.

The presented model allow to specify the technological complex of works and the need for raw materials, provide an opportunity to establish boundaries between the complex of works, for which the producers-executors are responsible and, in general, the responsibility of the entire corporate structure of food production.

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Lyapunov Exponents as Indicators of the Stock Market Crashes

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Abstract. The frequent financial critical states that occur in our world, during many centuries have attracted scientists from different areas. The impact of similar fluctuations continues to have a huge impact on the world economy, causing instability in it concerning normal and natural disturbances [1]. The anticipation, prediction, and identification of such phenomena remain a huge challenge. To be able to prevent such critical events, we focus our research on the chaotic properties of the stock market indices. During the discussion of the recent papers that have been devoted to the chaotic behavior and complexity in the financial system, we find that the Largest Lyapunov exponent and the spectrum of Lyapunov exponents can be evaluated to determine whether the system is completely deterministic, or chaotic. Accordingly, we give a theoretical background on the method for Lyapunov exponents estimation, specifically, we followed the methods proposed by J. P. Eckmann and Sano-Sawada to compute the spectrum of Lyapunov exponents. With Rosenstein's algorithm, we compute only the Largest (Maximal) Lyapunov exponents from an experimental time series, and we consider one of the measures from recurrence quantification analysis that in a similar way as the Largest Lyapunov exponent detects highly non-monotonic behavior. Along with the theoretical material, we present the empirical results which evidence that chaos theory and theory of complexity have a powerful toolkit for construction of indicators-precursors of crisis events in financial markets.

Keywords. Complex dynamic systems, unstable, chaotic, recurrence plot, Lyapunov exponents, stock market crash, indicator of the crash

1 Introduction

The frequent financial critical states that occur in our world, during many centuries have attracted scientists from different areas. Such events appear to be the embodi-

ment of chaos and chaotic behavior that has been the subject of research in various fields, especially in economics and finance. The impact of similar fluctuations continues to have a huge impact on the world economy, causing instability in it concerning normal and natural disturbances [1]. The anticipation, prediction, and identification of such phenomena remain a huge challenge. In recent years there has been developed a plurality of different models and methods to predict future performance [2-7], but from observed results, there is no clear evidence of one approach for others. This became especially evident in the context of the current coronavirus global economic crash of 2020.

Further events such as the Russian crisis in 1998, the Argentinian crisis in 2001, and the global financial crisis in 2008 [8] that caused a strong influence on the financial markets and the global economy, show strong contagion effect and nonlinearity. Similar conclusions were made based on many articles related to the paradigm of nonlinear data analysis. For example, Zeman compared the chaotic behaviors of Thailand in 1998 and Greece in 2013 in terms of economic indicators like GDP, unemployment, exports, government debt, etc. without any further analysis [9]. Mattarocci G. [10] using a large number of world stock indexes, try to identify the main market characteristics that influence dynamics. During this study author carried out having recourse to the Rescaled Range Analysis (R/S) approach, shows that the market's characteristics, like liquidity, type of admissible orders and so on, influence the R/S capability to study returns dynamics. Also, some evidence of nonlinear and chaotic phenomena in the literature related to capital markets was revealed starting with Hsieh's contribution [11].

The stock markets are a kind of a complex system with all kinds of interactions that represent nonlinear characteristic in its dynamics. With the first contribution [12] on chaos phenomena in the economic system, there were plenty of research papers devoted to this topic [13-15]. However, even though, there are still left some discussions and differences of opinion regarding the presence of chaos in financial systems. And yet the provided results show that the financial time series represent some little evidence of chaotic dynamics. Other researchers [16] pointed out that, nowadays, it is difficult to distinguish the exogenous noise from chaos with the available techniques, methods, and models. Thus, it may not be chaos as a whole. However, we believe that there may be hidden some chaotic properties in a subset of data.

In our contribution, we investigate changes in the dynamical properties of the financial datasets before a crisis event occurs using Lyapunov exponents (LE), which recommended themselves as a great tool for chaos quantification and indication. The key idea in this contribution, which we will ahead to throughout our research, is that the trajectory of the system and its complexity must diverge before the crisis state. This divergence of the system should have the corresponding degree of chaotic patterns that our indicator can detect and monitor. Such an advantage allows us to use these instruments in predictive settings.

This paper is organized as follows: The brief list of literature devoted to chaos in finance and chaos detection in it with LE is given in Section 2. Definition of the LE methods that we use for its computation, and empirical results we present in Section 3. Some concluding remarks and future perspectives are given in Section 4.

2 Review

With the high growth in computer science, computer simulations of complex and chaotic systems become increasingly appreciated. For at least two decades, with development in numerical computations and quantitative analysis, no doubt left that chaos theory suggests the same unstable fluctuation that may be as common as the extreme events and critical transitions in financial markets. For instance, Scheinkman and LeBaron [17] explored several indications of nonlinear dynamic structure in stock market returns. In their opinion, the weaknesses of such studies are based on time series that are not long enough to reveal the strange (fractal) attractors. On the other hand, the reason may be chaos that comprises a class of signals intermediate between regular periodic or quasiperiodic motions and unpredictable, truly stochastic behavior [18]. Kulkarni S. in her paper [19] denotes that, probably, random financial fluctuations often exhibit varying levels of fluctuations, chaos. Her paper represents the efficiency of Lyapunov exponents for the complexity analysis of shortly limited data. The analysis represents weakly chaotic behavior which alternates with non-chaotic over the entire period of analysis.

Lyapunov exponents are a natural first choice in exploring and indicating such chaotic behaviors that occur in it. They do not only classify the system but also tell us the limits of predictability of the chaotic system [18]. During the last few decades, there was plenty of scientific researches that were related to chaos systems, chaos behavior and, namely, to the Lyapunov exponents. The earliest papers, in which authors [20, 21] try to use Lyapunov exponents to detect chaos dynamics in financial time series, it is determined that linear, deterministic processes are characterized with negative Lyapunov exponents from nonlinear, deterministic processes with the largest exponent (where it is positive). Besides, there is an article [22] in which Gençay presents a methodology to compute the empirical distributions of Lyapunov exponents using a blockwise bootstrap technique. This method provides a formal test of the hypothesis that the largest Lyapunov exponent equals some hypothesized value, and can be used to test the system for the presence of chaotic dynamics. Such methodology is particularly useful in those cases where the largest exponent is positive but very close to zero.

Sarkar S and Chadha V. [23] in their paper investigated the local fractal and chaotic properties of financial time series by calculating two exponents, the Local Hurst Exponent and Lyapunov Exponent. As it is seen in their research, all calculations were made with the algorithm of a moving time window, where they have considered two major financial indices of the US: the Dow Jones Industrial Average (DIJA) and S&P 500. Based on the considered measures, they attempted to predict the major crashes that took place in these markets.

Srinivasan S. and others in their paper [24] have provided an explanation and motivation for reconstructed phase spaces using the methods of time delay and SVD embedding. They explained the meaning of LE and an algorithm for its estimation for the corresponding chaotic, deterministic, and periodic time series. From their presented results it is seen that estimated positive and zero exponents converge to the expected, documented values. Mastroeni L. and Vellucci P. [25] obtained empirical

results with the help of Maximal Lyapunov Exponent (MLE) and a determinism test that shows that commodity and futures prices are representatives of a nonlinear deterministic, rather than stochastic systems. Similarly to [23], Plakandaras V. et al [26] measure the Hurst exponent and LE in the sliding window to focus on persistence and chaotic behavior – two prime characteristics of uncertainty indices. For such purpose, they analyze 72 popular indices constructed by forecasting models, text mining from news articles and data mining from monetary variables. More specifically, researchers found that almost all uncertainty indices are persistent, while the chaotic dynamics are detected only sporadically and for certain indices during recessions of economic turbulence. Authors of empirical analysis [27] in one of their chapters explore whether the global markets are intrinsically unstable where unpredictability, disorder, and discontinuities are inherent and not aberrations. They investigate a huge amount of literature and examine the possible non-linear, particularly chaotic nature of the global stock markets. Their study explores the possible presence of chaos in two phases: over the period for 1998-2005 and from 2006 to 2011. Over 30 indices have been investigated. Empirical results show that for the first phase, 29 indices are deterministic. But 10 of them are found to be non-chaotic. Estimated determinism factors for all the indices are quite high, but Lyapunov exponent is presented to be non-positive for at least 6 of them, where others are chaotic, especially all the US and American indexes.

As it is seen, chaos theory and its tools remain a huge challenge for researchers of different fields of science and, namely, in the financial industry, and, as it was suggested in [26], the examination of persistent and chaos should be a prerequisite step before using financial indices in economic policy model. The world of Lyapunov exponents remains a growing interest in their definition, numerical methods, and application to various complex systems. This is why, throughout the article, we discuss different methods and applications and try to apply several of them to the financial time series and indicate possible critical states.

Throughout our research, following the line of a growing body of literature, it was noticed that despite the huge number of the research papers related to the topic of Lyapunov exponents, there is a small number of papers devoted to the topic of their construction as predictive indicators in the stock market. Therefore, relying on methods and tools described in our previous papers [28-31], we emphasized three the most well-known and correlated stock indices, specifically DAX, HSI, and S&P 500 of verifiable fixed daily values (<https://finance.yahoo.com>) and construct for them indicators that should indicate in a specific way to the crashes events. Main crashes we emphasize relying on the list of stock market crashes and bear markets (https://en.wikipedia.org/wiki/List_of_stock_market_crashes_and_bear_markets). Further research due to the limitations of this paper will include the results only for DAX index, but as the indices are correlated, the results will be almost the same. Each calculation was carried out for the original time series within the framework of the algorithm of a sliding window [28]. Subsequent empirical results were obtained within windows of length 500 and 1000 days, and a time step of 5 days. Presented results will consider only the DAX index, but the similar can be obtained and for others.

3 Lyapunov exponent and related methods

Lyapunov exponent is a measure of the exponential rate of nearby trajectories in the phase-space of a dynamical system. In other words, it quantifies how fast converge or diverge trajectories that start close to each other, quantifying the strength of chaos in the system. The divergence of such trajectories can be defined as

$$|\delta(t)| = |\delta(0)| e^{\lambda t} \quad (1)$$

where λ denotes the Lyapunov exponent; $\delta(t)$ is the distance between the reference point and its nearest neighbor after t iterations, $\delta(0)$ is the distance between the reference point and its nearest neighbor perturbed with small error at $t = 0$.

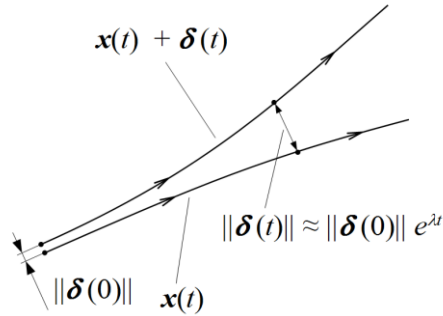


Fig. 1. Divergence of two initially close trajectories in a dynamical system.

In such cases when our system is multi-dimensional, we have as many Lyapunov exponents as the dimensions in it. The existence of at least one positive Lyapunov exponent is generally seen as a strong indicator of chaos. Positive LE means that initially similar, phase space trajectories that are sensitive to initial conditions and diverge exponentially fast, characterize chaotic behavior of the system. Negative LE responds to the cases when trajectories remain close to each other, but it is not necessarily implied stability, and we have to examine our system in more detail. Zero or very close to zero exponents indicate that perturbations made along the trajectory neither diverge nor converge. Exactly the largest Lyapunov exponent is used to quantify the predictability of the systems, since exponential divergence means that in the system where the initial difference was infinitesimally small, start to rapidly lose its predictability, behaving differently. However, it should be noted that other exponents also contain important information about the stability of the system, including the directions of convergence and divergence of the trajectories [32].

With the great interest in LE, more and more methods and proposals for their calculating have appeared. Unfortunately, there has not been obtained accepted and universal method for estimating the whole spectrum of Lyapunov exponents from a time

series data. One of the most common and popular algorithms have been applied by Wolf et al. [33], Sano and Sawada [34] and later improved by Eckmann et al. [35], Rosenstein et al. [36], Parlitz [37] and Balcerzak et al. [38]. Here, we followed the methods proposed by J. P. Eckmann and Sano-Sawada to compute the spectrum of Lyapunov exponents. With Rosenstein's algorithm, we compute only the Largest (Maximal) Lyapunov exponents from an experimental time series. As again suggested by Eckmann et al [39] one of the measures from recurrence quantification analysis can be considered for estimation of the Largest Lyapunov exponent since it detects in a similar way highly non-monotonic behavior.

3.1 Eckmann et al. Method

Firstly, according to the approach [35], we need to reconstruct attractor dynamics from a single time series $\{x_i\}_{i=1}^N$. For this purpose, according to the delay embedding theorem of Takens [40], we need to choose embedding dimension d_E . and after this, we construct d_E - dimensional orbit representing the time evolution

$$\bar{X}(t_i) = [x(t_i), x(t_i+1), x(t_i+2), \dots, x(t_i+(d_E-1))], \quad i=1, 2, \dots, N-d_E+1. \quad (2)$$

Then we have to determine the most neighboring trajectories with $\bar{X}(t_i)$:

$$\|\bar{X}(t_j) - \bar{X}(t_i)\| = \max_{0 \leq \alpha \leq d_E-1} \{|x(t_j + \alpha) - x(t_i + \alpha)|\}. \quad (3)$$

We sort the $x(t_i)$ so that $x(t_{\Pi(1)}) \leq x(t_{\Pi(2)}) \leq \dots \leq x(t_{\Pi(M)})$ and store the permutation Π and its inverse Π^{-1} . Then, we try to find the neighbors of $x(t_i)$ in dimension 1 by looking at $k = \Pi^{-1}(i)$ and scan the $x_{\Pi(s)}$ for $s = k+1, k+2, \dots$ and $k-1, k-2, \dots$ until $x(t_{\Pi(s)}) - x(t_i) > r$. For chosen embedding dimension $d_E > 1$, we select the value of s for which further condition is true

$$|x(t_{\Pi(s)} + \alpha) - x(t_i + \alpha)| \leq r, \quad \alpha = 0, 1, 2, \dots, d_E - 1.$$

Our next goal is to determine the $d_M \times d_M$ matrix M_i with a matrix dimension $d_M \leq d_E$, which describes time evolution of small vectors that surround trajectory $\bar{X}(t_i)$ and how they map onto $\bar{X}(t_i + m)$ trajectory after m iterations. The dimension d_M is chosen to avoid undetermined values in M_i . Due to this, we have larger step size m and then, associate with $\bar{X}(t_i)$ a d_M - dimensional vector such as

$$\bar{X}'(t_i) = [x(t_i), x(t_i + m), \dots, x(t_i + (d_M - 1)m)].$$

Accordingly to the algorithm, it is assumed that $d_E = (d_M - 1)m + 1$, therefore, $m = (d_E - 1) / (d_M - 1)$. In the case when $m > 1$, we need to estimate matrix M_i which best satisfies

$$M_i(\bar{X}(t_j) - \bar{X}(t_i)) \approx \bar{X}(t_j + m) - \bar{X}(t_i + m). \quad (4)$$

The M_i is then defined by the linear least-square method [41]. The last step of the algorithm is the classical QR matrix decomposition to find orthogonal matrices Q_i and upper-triangular matrices R_i with non-negative diagonal elements such that

$$M_{1+im}Q_i = Q_{i+1}R_{i+1}, \quad \text{for } i = 0, 1, 2, \dots$$

In order to calculate d_M Lyapunov exponents, the equation for the k^{th} Lyapunov exponent with K number of points on the attractor, for which the Jacobian has been estimated, the diagonal eigenvalues of the matrix R_i , and the sampling step τ is given by:

$$\lambda_k = \frac{1}{\tau m K} \sum_{i=0}^{K-1} \ln((R_{(i)})_{kk}).$$

Thus, with linearizations by using the diagonal elements from the QR decomposition, we can calculate Lyapunov exponents.

The calculation results for the MLE on the example of index DAX are presented in Fig. 2.

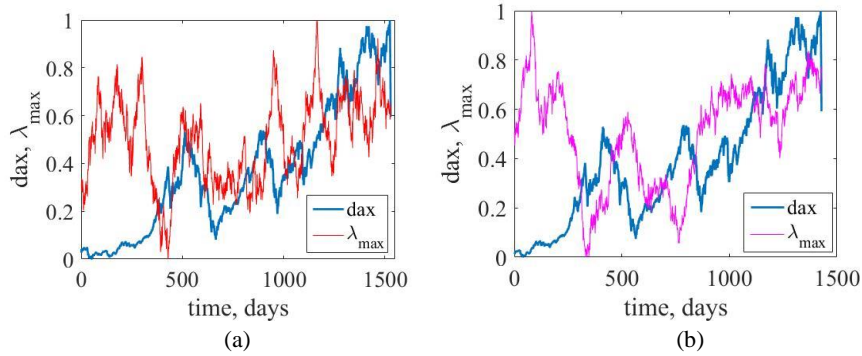


Fig. 2. The dynamics of the Maximal exponents calculated with Eckmann et. al. method within the time window of the length 500 days (a), 1000 days (b), and the time step of 5 days.

Let us pay attention to the behavior of λ_{\max} at the moments of the known failures noted in the list of stock market crashes and bear markets. Definitely, we can see that in the pre-crisis period, the value of MLE decreases markedly, then increases in the post-crisis period.

3.2 Rosenstein's et al. Method

Rosenstein's algorithm [36] uses the delay embedding method that reconstructs the most important features of a multi-dimensional attractor into a single one-dimensional time series of some finite size N . The reconstructed trajectory can be presented as $\bar{X} = [\bar{X}(t_1), \bar{X}(t_2), \dots, \bar{X}(t_M)]^T$. For the time series $\{x_i\}_{1 \leq i \leq N}$, each delay embedded vector $\bar{X}(t_i)$ will be presented similarly to the vector of the form (2) with embedding dimension d_E and time delay m . Then in the reconstructed trajectory we initialize searching for in the state space for the nearest neighbor $\bar{X}(t_j)$ of the trajectory $\bar{X}(t_i)$:

$$\delta_i(0) = \min_{|j-i| > \text{mean period}} \|\bar{X}(t_j) - \bar{X}(t_i)\|, \quad (5)$$

where $\|\cdot\|$ is the Euclidian norm, and $|j-i| > \text{mean period}$ denotes additional constraint that nearest neighbors have temporal separation greater than the mean period which can be calculated as the reciprocal of the mean frequency of the power spectrum, although authors of this method make a remark that they expect any comparable estimate. Such a condition gives us the possibility of considering each pair of neighbors as nearby initial conditions for different trajectories.

From (1), we have already known that the distance between states $\bar{X}(t_i)$ and $\bar{X}(t_j)$ will grow in time accordingly to a power law $\delta_i(k) = c \cdot e^{\lambda k}$ where λ is a good approximation of the highest Lyapunov exponent. For further estimations, we look at the logarithm of the distance trajectory $\ln \delta_i(k) \approx \lambda(k \cdot \Delta t) + \ln c_i$, where $\delta_i(k)$ is the distance between i^{th} pair of the nearest neighbors defined in (5) after k time steps, c_i is the initial separation of them and Δt is the time interval between measurements (sampling period of the time series).

Further result of this algorithm is not a numerical value, but a function of time:

$$y(k, \Delta t) = \frac{1}{\Delta t} \frac{1}{M} \sum_{i=1}^M \ln \delta_i(k),$$

where $M = N - (d_E - 1)\tau$ is the size of the reconstructed time series, and $\delta_i(k)$ represents a set of approximately parallel lines, each with a slope roughly proportional to the maximal exponent. Then, it is proposed to be calculated as the angle of inclination of its most linear section. Finding such a section turns out to be a non-trivial task, and sometimes it is impossible to specify such a section at all. Despite this problem, Rosenstein's method is easy for implementing and computing.

The MLE behavior for a window procedure with windows of different lengths is shown in Fig. 3.

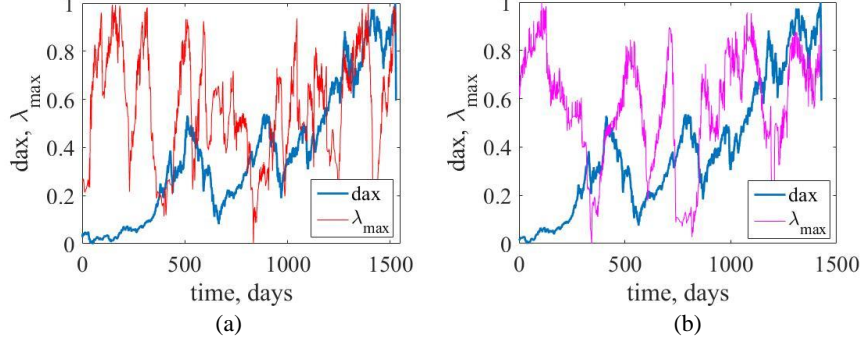


Fig. 3. The dynamics of the Maximal exponents calculated with Rosenstein et. al. method within the time window of the length 500 days (a), 1000 days (b), and the time step of 5 days.

It can be seen that, as before, MLE is also sensitive to the crisis conditions of the stock index.

3.3 Sano-Sawada Method

The method of Sano and Sawada [34] that is known in the literature as the Jacobian method, deals as previous ones with reconstructed trajectory as presented in (2). We will assume again that we are dealing with embedded vectors $\bar{X}(t_i) = [x(t_i), x(t_2), \dots, x(t_{i+d_E-1})]$ in d_E -dimensional space. Accordingly to (4), we denote by T some operator that transfers trajectories from states $\bar{X}(t_i)$ to $\bar{X}(t_{i+1})$.

The goal is to choose a sphere with a sufficiently small radius ε in the phase space trajectory \bar{X} . After m number of iterations, some operator T^m transforms this sphere into an ellipsoid with a_1, \dots, a_p semiaxes. If the system has s number of the positive Lyapunov exponents, then the sphere will stretch along the axes $a_1, a_2, \dots, a_s > \varepsilon$. Having an acceptable radius ε , operator T^m is going to be close enough to the sum of the shift operator and the linear operator A which eigenvalues we need to estimate. Then, by averaging these eigenvalues over the entire attractor, we get an estimation of the spectrum of Lyapunov exponents.

For these purposes, suppose that we have a vector $\bar{X}(t_i)$ for which we need to obtain the set of vectors $\{\bar{X}(t_{k_j})\}_{1 \leq j \leq N}$ that falls into the neighborhood of i^{th} trajectory within the ball of some radius ε :

$$\{y_j\} = \{\bar{X}(t_{k_j}) - \bar{X}(t_i) \mid \|\bar{X}(t_{k_j}) - \bar{X}(t_i)\| \leq \varepsilon\},$$

where y_j is the displacement between $\bar{X}(t_{k_j})$ and $\bar{X}(t_i)$ and Euclidean norm is defined as $\|w\| = \sqrt{(w_1^2 + w_2^2 + \dots + w_d^2)}$ for some vector $w = (w_1, w_2, \dots, w_d)$. After the evolution of a

time interval $m = \tau\Delta t$, the trajectory $\bar{X}(t_i)$ will be mapped to $\bar{X}(t_{i+m})$ such as their neighbors. Then the displacement vector y^j will proceed to

$$\{z_j\} = \{\bar{X}(t_{k_j+m}) - \bar{X}(t_{i+m}) \mid \|\bar{X}(t_{k_j}) - \bar{X}(t_i)\| \leq \varepsilon\}.$$

If the corresponding requirements were accomplished, then the evolution of y_j to z_j can be described by the operator A_i . For its optimal estimation, the least-square error algorithm can be a plausible procedure which minimizes the average of the squared error norm between z_j and $A_i y_j$ with respect to all components of the matrix A_i as follows:

$$\min_{A_i} S = \min_{A_i} \frac{1}{N} \sum_{j=0}^N \|z_j - A_i y_j\|^2. \quad (6)$$

Denoting the component of matrix A_i by $a_{kl}(i)$, where k is a row, l is a column of the matrix and applying condition (6), we obtain $d_M \times d_M$ system of equations of the form:

$$A_i V = C, (V)_{kl} = \frac{1}{N} \sum_{j=1}^N y_j^k y_j^l, (C)_{kl} = \frac{1}{N} \sum_{j=1}^N z_j^k y_j^l, \quad (7)$$

where V, C are $d_M \times d_M$ -dimensional matrices, y_j^k is the k^{th} component of the vector y_j , and z_j^k is the k^{th} component of the vector z_j . If A is considered to be a solution of the equations above, then the spectrum of Lyapunov exponents can be calculated by the following formula:

$$\lambda_j = \lim_{n \rightarrow \infty} \frac{1}{n\tau} \sum_{i=1}^n \ln A_i e_j^i,$$

where A is the solve of the equations (7), and $\{e_j\}$ is the set of basis vectors in the tangent space $\bar{X}(t_j)$.

The MLE dynamics for the DAX index is presented in Fig. 4.

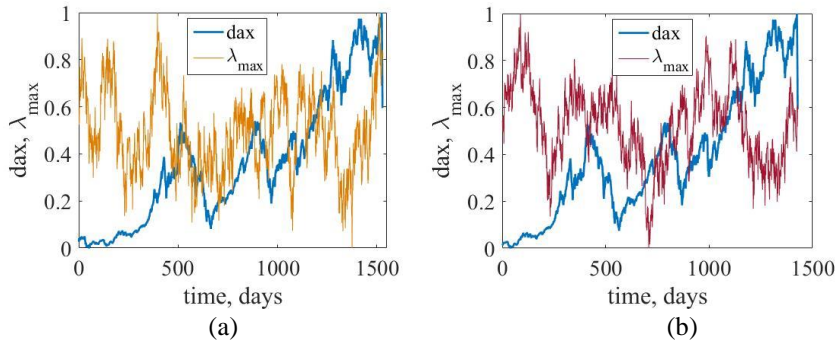


Fig. 4. The dynamics of the Maximal exponents calculated with Sano and Sawada method within the time window of the length 500 days (a), 1000 days (b), and the time step of 5 days.

Note that the presented method is the worst of those considered in the sense of sensitivity to crashes. Given that it requires a rather long time series to obtain a positive sign for MLE. Therefore, it can hardly be recommended for use as an indicator of crashes.

3.4 Recurrence Quantification Analysis

Recurrence plots (RPs) have been introduced to study dynamics and recurrence states of complex systems [42, 43]. Similar to previous examples, a phase space trajectory (Fig. 5a) can be transformed from a time series into time-delay structures.

RP is a plot representation of those states which are recurrent (Fig. 5b). The recurrence matrix and the states are considered to be recurrent if the distance between them within the ε - radius. In this case, the recurrence plot is defined as:

$$R_{ij} = \Theta(\varepsilon - \|x_i - x_j\|), \quad i, j = 1, \dots, N,$$

and $\| \cdot \|$ is a norm (representing the spatial distance between the states at times i and j), ε is a predefined recurrence threshold, and Θ is the Heaviside function (ensuring a binary \mathbf{R}).

For the quantitative description of the system, the small-scale clusters such as diagonal and vertical lines can be used. The histograms of the lengths of these lines are the base of the recurrence quantification analysis [43].

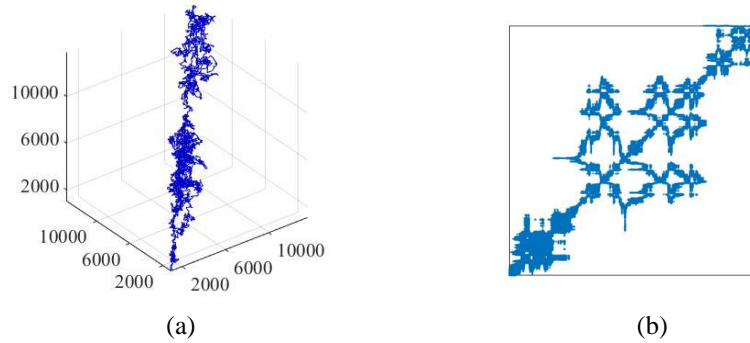


Fig. 5. Phase portrait (a) and corresponding RP (b) for DAX index.

Different elements of RP are distinguished and used, introducing different quantitative measures of complexity of recurrence diagrams. For our purposes, linear sections (lines) of the diagrams are important, which are consecutive sets of individual points. The black dots represent the recurrence of the dynamical process determined with a given resolution ε , and their organization characterizes the recurrence properties of the dynamics. A vertical line of length l starting from a dot (i, j) means that the

trajectory starting from x_j remains close to x_i during $l-1$ time steps. A diagonal black line of length l starting from a dot (i, j) means that trajectories starting from x_i and x_j remain close during $l-1$ time steps, thus these lines are related to the divergence of the trajectory segments. The average diagonal line length

$$L = \frac{\sum_{l=l_{\min}}^N lP(l)}{\sum_{l=l_{\min}}^N P(l)}$$

is the average time that two segments of the trajectory are close to each other, and can be interpreted as the mean prediction time. Here $P(l)$ is a histogram of diagonal lines of length l .

Another measure considers the length L_{\max} of the longest diagonal line found in the RP, or its inverse, the divergence,

$$L_{\max} = \max(\{l_i\}_{i=1}^{N_i}), \text{ and } Div = 1/L_{\max},$$

where $N_i = \sum_{l \geq l_{\min}} P(l)$ is the total number of diagonal lines. These measures are related to the exponential divergence of the phase space trajectory. The faster the trajectory segments diverge, the shorter are the diagonal lines and the higher is the measure Div . Therefore, the measure of Div , according to Eckmann [39], can be used to estimate the largest positive Lyapunov exponent.

The comparative dynamics of the $Div \simeq \lambda_{\max}$ measure and the DAX index are presented in Fig. 6.

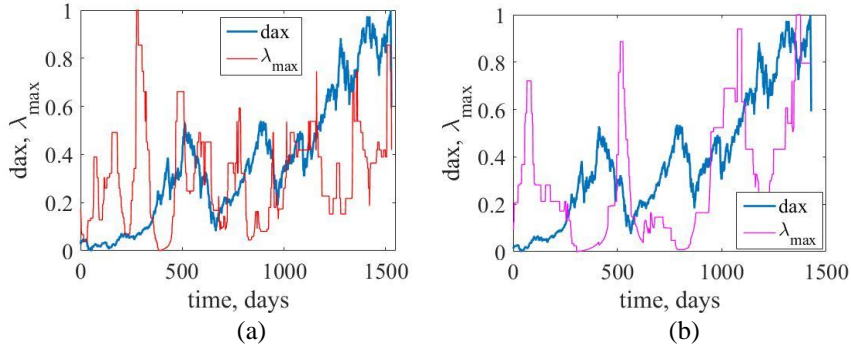


Fig. 6. Recurrent stability measures for windows of 500 (a) and 1000 (b) days in size.

A comparative analysis of the measures under consideration revealed an obvious advantage of the recursive measure. In addition to the smoothness of the measure itself, it can be calculated for windows of small sizes, which leads to inaccurate or incorrect results for other methods.

This research has made it clear that all three indices represent the behavior of deterministic and chaotic behavior in which the majority of crashes can be identified using the Maximal Lyapunov Exponent.

Fig. 7a presents the comparative dynamics of the daily values of the selected indices DAX, HSI, and S&P 500 with the considered dates of the main crashes. Fig. 7b illustrates the dynamics of the absolute values of the three highest Lyapunov Exponents for method Eckmann and the Maximal LE calculated by method Rosenstein ($R \lambda_{\max}$) and method Sano-Sawada, implemented in the well-known Tisean package ($T \lambda_{\max}$).

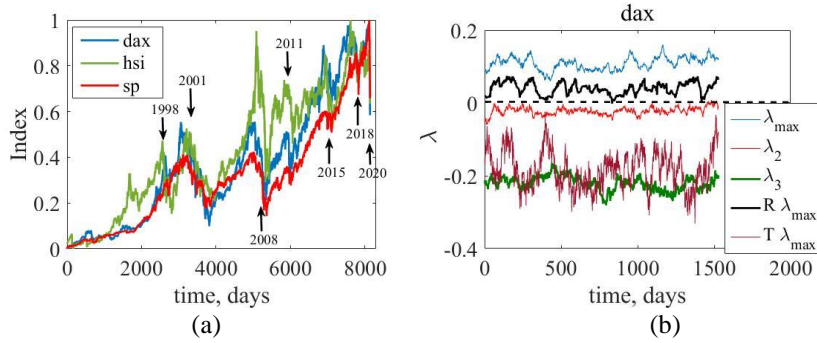


Fig. 7. The dynamics of the stock indices: DAX (dax), HSI (hsi), S&P 500 (sp) (a). The calculated spectrum of the Lyapunov Exponents and the MLE following the methods presented below (b). Selected window length of 500 days and increment of 5 days.

As can be noticed from Fig. 7b, for the method Rosenstein ($R \lambda_{\max}$) we have the slightly positive MLE values which can assure us of the chaotic and deterministic behavior which is peculiar to this market. The Sano-Sawada method gives negative MLE values, which most likely indicates method errors for short time series. Calculations show that positive MLE values stably indicate a chaotic picture only starting from windows larger than 1500.

4 Conclusions

The stability problems of financial markets in general and stock markets in particular, deserve more attention in order to ensure their stability and minimize losses as a result of critical changes. The methods of nonlinear dynamics make it possible to identify special states of complex dynamical systems, classify them, and indicate possible trajectories of motion. One of such universal tools for nonlinear dynamics is the spectrum of Lyapunov exponents, the largest of which determines the rate of spread of the trajectories of a dynamical system in phase space. If it is positive, the system is unstable and can assume chaotic states. The disadvantage of many classical methods for determining LE was the need to have a sufficiently long time series, otherwise, the results were irreproducible or incorrect. Moreover, it is interesting to observe the change in LE over time, identifying its characteristic changes. Comparing them with those for the initial series, we can try to predict the possible states of the system under study.

In this work, we have demonstrated the possibility of using LE as an indicator of stock market crashes. In the pre-crisis period, LE is markedly reduced, signaling a more predictable state. In a crisis, the growth of LE indicates the growth of the chaotic component of the market. Particularly promising are the relatively new methods for calculating LE based on the recurrent properties of the system and providing acceptable accuracy for short time series. Of interest is the scale-dependent version of the LE [44], to which we plan to devote a separate article.

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Simulation of Agricultural Policy Scenarios Using the AGMEMOD Model

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Abstract. The article considers and generalizes using evolutionary models of economics on the AGMEMOD model example - a partial equilibrium, dynamic, multi-country, and multi-market model that is used for analyzing the effects of agricultural policies on the respective sectors of each EU Member State and the EU as a whole. The use of the AGMEMOD model was illustrated in the example of designed specific scenarios of the development of the biofuel market in Ukraine until 2030. The practical application of the development is the possibility of using the research results by the relevant state institutions to stimulate the development of the biofuel market in Ukraine. The simulation example described in this paper can also be used by scientists from other countries to predict the impact of agricultural policy on the economy.

Keywords: AGMEMOD model, Simulation analysis, Mathematical programming, Biofuel market.

1 Introduction

The simulation economic systems are very important for understanding future trends of the contributions of such systems to the national economy. In this case, computer modeling becomes an essential tool for the national planning of economic processes.

The Member States in the EU can adopt different positions in respect of policy proposals, based on their assessment of the merits of the policy for their agriculture sector and the whole economy. Who charged with developing policy proposals at the EU level, should have an appreciation for the likely impact of a particular policy in order to identify, at an early stage, any problem that would prevent a policy proposal's acceptance by the Member States. For this purpose, a model such as the AGMEMOD model will be highly useful for EU and Member State based policymakers.

The main aim of the article is to substantiate the scenarios of biofuel market development in Ukraine till 2030.

This paper has been divided into several parts. The second part deals with a brief presentation of previous studies in this field, the nowadays trends, and the research methodology, to be able to theoretically substantiate using the econometric AGMEMOD model for making policy decisions in economics.

The third section highlighted is a description of the model's practical use of the model for making policy decisions in economics on the example biofuel sector that was realized and was implemented in the model AGMEMOD for the first time.

Finally, the conclusion gives a summary and critique of the findings, the model's limits, and the importance of using the model as IT instruments for making policy decisions in economics.

2 Theoretical and Methodological Background

2.1 The AGMEMOD Model and Other Simulation Models

Computer simulations are a powerful and useful research tool available to scientists to study the behavior of systems in different areas especially in the economy, among others whose performance depends on multiple dynamic variables acting simultaneously.

Research is based on the intersection of computer science and economics has been widely used in recent years and is a source of great interest and excitement for both disciplines. One of the advantages of a simulation system is that it can be used to study the dynamic behavior of systems in situations, where real systems cannot be easily or safely used and can also be applied to understand and evaluate "what-if" case scenarios [1-8].

Hayenga, M. et al. [9] determines the computer simulation as a systems analysis tool that utilizes subject matter theory, certain mathematical structures, programming logic and empirical analyses to condense a complex system into a mathematical formulation duplicating to the essence of the real system. On top of that, they believe that computer simulation is the best planning tool in developing economies.

Economic models are a simplified representation of economic reality, showing the interrelationships between selected economic variables. They are used to analyze the impacts of policy and market changes. The most common approaches for quantitative assessments of policy reforms and market changes are based on partial equilibrium (PE) and general equilibrium (GE) programming models [10].

Models for simulation agrarian policy are potentially relevant tools for policy impact assessment [11]. The methodology of analyzing the agriculture sector involves the use of a system of models and their program implementation, which provide multivariate analytical and predictive calculations. There are two types of models for agro-economic system: partial equilibrium and computable general equilibrium models.

Van Tongeren et al. [12] have given an overview of the most significant models used for agricultural economic analysis and classify them following specific criteria: a regional unit of analysis, treatment of quantitative policies, the scope of representation, dynamics, trade representation, regional scope, availability of data and parameter estimation. Taking into account this methodological classification, a sub-sample of well-

established models was selected in order to shape the construction of an Integrated Modeling Platform for Agro-economic Policy Analysis (iMAP) in the premises of the Joint Research Centre in Seville (JRC -IPTS) in close collaboration with DG AGRI [13].

The AGLINK model is a partial equilibrium, a recursive-dynamic, supply-demand model of world agriculture, developed by the Organization for Economic Cooperation and Development Secretariat, in close co-operation with member countries and certain Non-Member Economies as well as with the Food and Agricultural Organization of the United Nations. The model covers annual supply, demand, and prices for the principal agricultural commodities produced, consumed, and traded in each of the countries represented in the model. The model focuses, in particular, on the potential influence of agricultural and trade policies on agricultural markets in the medium term.

The examples of partial equilibrium models are ESIM and WATSIM. These models simulate the future effects of the policy reforms on trade, production, consumption, and domestic prices of a wide range of EU countries from a static perspective. Changes of these models in the rest of the sectors of the economy are considered only exogenously and parameters of the functions are calibrated to the values of the models' reference year.

An example of the computable general equilibrium is the GTAP model. The model is characterized by global coverage and simulates the development of all the sectors of economies of the countries considered. Moreover, the model also includes linkages and feedbacks between the sectors and can simulate bilateral trade flows between the countries [14]

AGMEMOD is a partial equilibrium model [15] that estimates future effects of the policy reforms on the agricultural sector of the EU and few non-EU countries on a year-to-year basis (i.e., dynamic perspective). Unlike AGMEMOD, CAPRI [16] is a static model and includes only EU countries. The main difference between the two modeling systems used in these models is that in AGMEMOD, parameters of the core functions (e.g., consumption, yields, animal stocks) are estimated econometrically, and in CAPRI, mathematical programming technique is used for estimation of the land-use change.

AGMEMOD is a modeling tool designed to analyze European agriculture and the Common Agricultural Policy (hereinafter - CAP) and this model is very popular in the EU and there is a lot of researches related to applying it for simulation of changes in agricultural policy and its assessment [17].

For example, the Finnish AGMEMOD model includes the building blocks of the national policy models. The specific goal of the Finnish modeling project was to build a country model on a common format so that it would link-up to provide an integrated model for the whole EU. The policy changes in the model is demonstrated by comparing the results of different policy scenarios with that of the baseline scenario [18].

Mariusz Hamulczuk & Katarzyna Hertel [19] presented the using of partial equilibrium models in the the agri-food sector. One of the most important reforms carried on

currently by the European Commission in this sector is the dairy market reform. Therefore, a modeling of milk quota abolition for the Polish dairy sector was performed and displayed as an example of the model application.

The AGMEMOD model stands for Agricultural Member State Modelling and was established in 2001. The AGMEMOD Partnership has developed the model, which currently contains the EU27 member states, as well as the countries Macedonia, Croatia, Russia, Ukraine, and Turkey.

The AGMEMOD Partnership develops and maintains the model and is a consortium of numerous universities and research institutes across Europe and beyond. The core group of the AGMEMOD Partnership is located in the Netherlands (Wageningen Economic Research) and Germany (Thünen Institute of Market Analysis) and combines, coordinates the work done with the model.

The model includes about 50 agricultural products (including product groups) in about 35 countries (including country groups), which allows assessing the impact of policy decisions on the agrarian sector and modeling the future development of relevant indicators. Most of the equations in the model have been estimated using annual data over the period 1973-2017, or over shorter periods in case of data were not available (such as for the new member states). The variables entering in each sub-model represent consecutive positions in the balance sheet of each market. By the supply side are represented the beginning stocks, production, and imports and on the demand side the domestic use, exports, and ending stock are modeled. In each country for each product, also the respective domestic prices (market-clearing prices) are modeled. In each market, the equilibrium is reached in the model also on the level of the whole EU.

The model uses a combination of exogenous and endogenous data to create projections of agricultural market development. The AGMEMOD relies on some exogenous variables, values of which are not estimated by the model, but by other organizations. They include projections of the world market prices of major agricultural commodities such as corn, barley, wheat, oilseeds, beef, pork, poultry, and other types of meat, milk, and dairy products. Furthermore, the model includes the following macroeconomic exogenous parameters which currently include population number, national currency exchange rates, Gross domestic product (GDP), and GDP deflator. The inclusion of exogenous variables allows a better representation of the processes and linkages in the agricultural sector and each of the exogenous variables affects variables estimated by the model.

2.2 The Authors' Contribution to the Development of the AGMEMOD Model

In the framework of Deep and comprehensive free trade area agreement between Ukraine and the EU (hereinafter – DCFTA) from 2014 Ukraine set a course on reformation of its agricultural policy to less regulated and more market oriented. To help Ukraine in dealing with this task, the German-Ukrainian Agricultural Policy Dialogue took initiative to develop an advanced up-to-date tool for quantitative assessment of the effects of policy measures on the agricultural sector of Ukraine. For this purpose and

following the best practices of the EU and Germany, the AGMEMOD model, the economic policy simulation model of the agricultural sector, was chosen. Since 2018 Faculty of Economic Sciences of The National University of Life and Environmental Sciences of Ukraine (Kyiv) has launched a new analytical laboratory AGMEMOD.

AGMEMOD-Ukraine has three main modelling blocks: database (CC-Datagmemod_Base.xlsx), model specification (CountryTimeSet_Baseline.xlsm, PolicyHarmon_Baseline.xlsm) and modeling assumptions (AssumptionsInput_Baseline.xlsm) (Fig. 1).

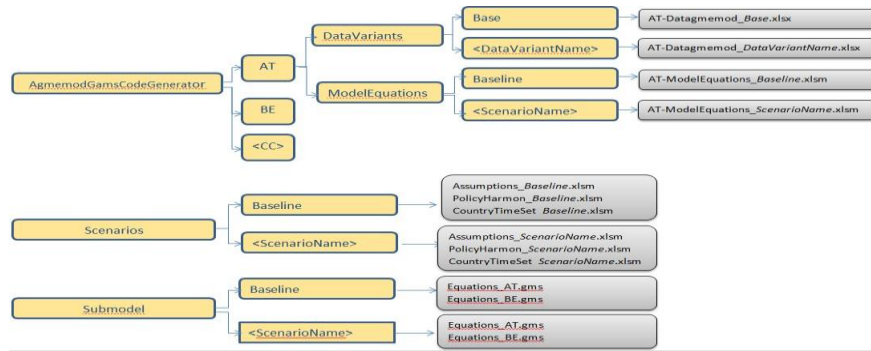


Fig. 1. The model's internal structure on data and scenario variants

From this perspective, Figure 1 shows how model's internal structure has been organized regarding: the country commodity databases (Data variant dependent); the econometrically estimated country model equations (Scenario dependent); the macro, policy and other assumptions (Scenario dependent). At the same time, Figure 1 shows the rationale behind the naming conventions connected to the data variant name use and the scenario name used.

The Database of the model includes historical data on prices, quantities produced, used, imported, and exported of the commodities included in the model. Currently, AGMEMOD-Ukraine holds the following commodities: wheat, corn, oats, rye, barley, rape-seed seeds, oil and meal, sunflower seeds, oil and meal, soya beans, oil and meal, beef, pork, poultry, lamb, milk and milk products, eggs.

With each creation of a new data variant and/or scenario, its associated subfolder and file naming structures are automatically generated by the program according to the structure shown in the figure.

Model runs under a researcher friendly framework (GsePro.exe program), which will be indicated in this paper as the AGMEMOD tool. In particular, the Agmemod2Gams tool plays the main role as an intermediary between the development of the conceptual model and the development of the computer model [20].

Taking into account the commitments undertaken by Ukraine with the accession to the Energy Community, the Resolution of the Cabinet of Ministers of Ukraine dated October 01, 2014 No. 902 approved the "National Renewable Energy Action Plan for the period up to 2020" (hereinafter – NREAP), which established mandatory national

indicative targets for the use of renewable energy sources with final energy consumption in the transport sector in 2020 – 10% [21]. According to the Energy Strategy of Ukraine until 2035, the share of green energy in the overall consumption will be 25% in 2035 [22]. However, the actual results of renewable energy sources (RES) development threaten to fail to meet the planned targets: in 2018, the share of RES in the energy balance was only 2%, which is almost 5 times less than the 2020 target [21]. According to many experts, the slow pace of growth of “green” energy in the country is conditioned by the imperfection of existing economic mechanisms managing and supporting the development of this sector.

Provided the appropriate framework conditions it is worth to consider Ukraine's ability to achieve the above objectives for the consumption of liquid biofuels by the transport sector, analyze the state of the biofuel production in Ukraine, identify the obstacles that exist in achieving the mandatory national indicative targets, assess the feasibility of implementation taken on Ukraine's international obligations regarding motor biofuels, and propose measures to enable the obligations. Growing demand for biofuels in the world poses a question on Ukraine's potential of its production, as the country is large grain and oilseed producer.

For the first time in Ukraine in 2019, we realized the abovementioned goals and was designed a new sector in the AGMEMOD model – biofuel sector (Fig. 2).

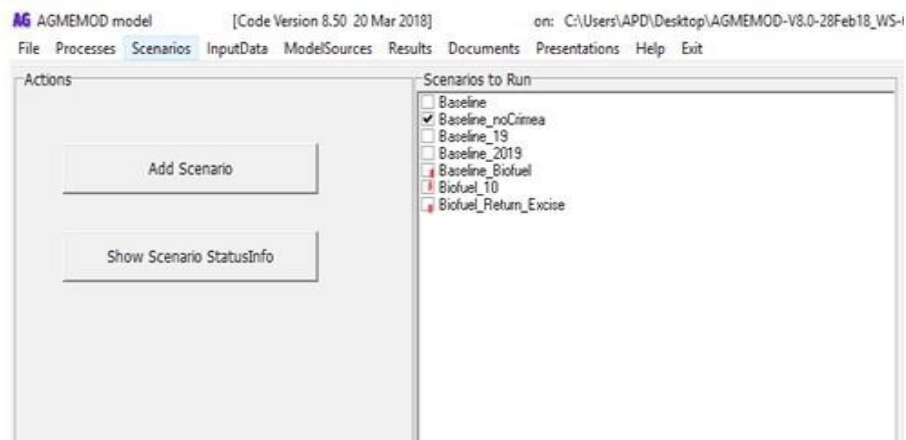


Fig. 2. Created Biofuels Scenarios in the model

In particular, the Ukraine country model was enlarged to include the use of crops for bioethanol and biodiesel production and the respective domestic market indicators (i.e., prices, export and import volumes, stocks, etc.). Wheat, corn, rye, sugar beet, rapeseed, sunflower seeds, and soya beans are currently and potentially the main sources for bioethanol and biodiesel production in Ukraine. Although markets of these crops are already presented in the AGMEMOD Ukraine country model, the use of these crops for biofuel production and the respective market indicators we have introduced as well. In

particular, domestic market prices, production, import, export, final stocks and domestic use quantities of biofuels produced from each of the above-mentioned crops were incorporated.

The main data for our research was collected from publications of State Statistics Service of Ukraine (SSSU), personal communication with the largest biofuel producer in Ukraine “Ukrspyr” and with the Ukrainian association of alternative fuels producers “Ukrbiopalivo”. The exogenous future values of variables (by 2030) of the model (that is not estimated by the model), such as GDP, GDP deflator, the exchange rate of the national currency, and world diesel, gasoline prices, gasoline and diesel consumption in Ukraine, excise duty on alternative motor fuel, on gasoline and biodiesel, are forecast estimates of various institutions. The world market prices are FAO, OECD, projections, and macroeconomic parameters – USDA (United States Department of Agriculture) projections.

To create a comprehensive GAMS dataset that was used to solve the combined model all common exogenous data (stored in AssumptionsInput.xls and PolicyHarmon.xls) and specific Ukraine country data (stored in CC-Datagmemod.xls) were read.

The model is specified by econometrically estimated functions of key model parameters and algebraic identities. If data for function estimation is not available, the functions are calibrated. The calibration of specific model parameters is most often necessary where short and incomplete data series prevent the use of regular estimation procedures. In such cases, some parameters are chosen on the basis of estimates available from the literature, expert knowledge, or results obtained from similar equations in other country models. The remaining parameters, such as possibly time trend parameters and the constant term are estimated to fit the equation as much as possible to the available statistical data.

The collected data allowed solving the model for market equilibrium and were estimated in R version 3.4.4 software as time-series regressions. For data processing (regularization, decomposition, and analysis of space-time series), we used the R package “pastecs”, for estimation linear regression models for our research was used “dyn” and “plm” packages. Their R code fragment is shown in Fig. 3 and Fig. 4.

```
1 # package required for descriptive statistics (stat.desc comm
2 # install.packages("pastecs")
3 library(pastecs)
4 # export regression results
5 # install.packages("stargazer")
6 library(stargazer)
7 # to use lagged operator
8 # install.packages("dyn")
9 library(dyn)
10 # numbers are printed in a fixed notation, unless they are mo
11 options(scipen=50)
12 # set the number of digits to print when printing numeric val
13 options(digits=2)
```

Fig. 3. The R code fragment for uploading R packages for processing datasets

```

34
35 ##### biofuel use in cereal sector (bioethanol) from
36
37 wheat_ethanol <- subset(biofuel, select=c("Year", "WSUFBUA",
38 "WSPFNUA", "dummy",
39 "ETWMPRIE_EXRDU",
40
41 wheat1 <- dyn$lm(WSUFBUA ~ ETPFNUA_R + dummy, data=biofuel)
42 summary(wheat1)
43 stargazer(wheat1,
44 type="text",

```

Fig. 4. The R code fragment of using R package “dyn” for estimation linear regression of the bioethanol from wheat

For making visualization researching variables during estimation of our models we used the function “plot”, the histogram, and normal probability plot to indicate that the normal distribution provides an adequate fit for these models. In Fig.5 are shown the R function “plot” for making visualization of model variables.

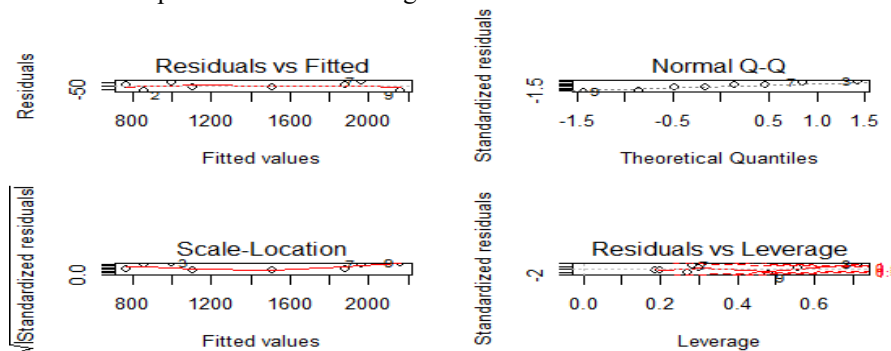


Fig. 5. R function “plot” for making visualization of model variables

To provide a regression diagnostic, particularly graphical diagnostic methods we used R packages “car”, for cleaning and working with data was made use of “tidyverse” packages. To test the hypothesis of modeling was made by the estimation for the original dataset with using “IMTest” package (Fig.6).

```

49 install.packages("tidyverse")
50 library(tidyverse)
51 install.packages("readxl")
52 library(readxl)
53 install.packages("car")
54 library(car)
55 # install.packages("plm")
56 library(plm)
57 # install.packages("IMTest")
58 library(IMTest)

```

Fig. 6. The R code fragment of using R packages for regression diagnostic and estimation of the original dataset

The dataset was integrated with the estimated country-level equations and stored in CC-Model Equations.xls (Fig. 7). The model was solved every year until 2030.

ENERGETIC CROPS	DIMENSION	MNEMONIC								
PRICES										
Bio ethanol price	UAH/100kg	ETPFNUA	ETPFN	ET	PFN	UA	IDEN	ETPFNUA = 571.0286 + 0.4194*GAPFNUA + 0.5375* GAEMFUA + 0.3759*FTEMFUA		
Bio diesel price	UAH/100kg	DZPFNUA	DZPFN	DZ	PFN	UA	IDEN	DZPFNUA = 450.247 + 0.579*DIIPFNUA + 1.595*OZEMFUA		
SUPPLY AND USE										
Wheat bio ethanol production	1,000 t	WBSPRUA	WBSPR	WB	SPR	UA	IDEN	WBSPRUA = WSUODUA*WSXTRUA		
Wheat bio ethanol imports	1,000 t	WBSMTUA	WBSMT	WB	SMT	UA	IDEN	WBSMTUA = max (0.001, WBUDCUA-WBSPRUA)		
Wheat bio ethanol exports	1,000 t	WBUXTUA	WBUXT	WB	UXT	UA	IDEN	WBUXTUA = max (0.001, WBSPRUA-WBUDCUA)		
Wheat bio ethanol final stocks	1,000 t	WBUCTUA	WBUCT	WB	UCT	UA	IDEN	WBUCTUA = 0.001		
Wheat bio ethanol domestic use	1,000 t	WBUDCUA	WBUDC	WB	UDC	UA	EQ_HFX	WBUDCUA = 49.751-0.234*(ETPFNUA/GOPDUUA)+1.749*WBSPRUA + 7.190*DBWB16		
Maize bio ethanol production	1,000 t	CBSPRUA	CBSPR	CB	SPR	UA	IDEN	CBSPRUA = COUODUA*COXTRUA		
Maize bio ethanol imports	1,000 t	CBSMTUA	CBSMT	CB	SMT	UA	IDEN	CBSMTUA = max (0.001, CBUDCUA-CBSPRUA)		
Maize bio ethanol exports	1,000 t	CBUXTUA	CBUXT	CB	UXT	UA	IDEN	CBUXTUA = max (0.001, CBSPRUA - CBUDCUA)		
Maize bio ethanol final stocks	1,000 t	CBUCTUA	CBUCT	CB	UCT	UA	IDEN	CBUCTUA = 0.001		
Maize bio ethanol domestic use	1,000 t	CBUDCUA	CBUDC	CB	UDC	UA	EQ_HFX	CBUDCUA = 60.745 + 1.352*CBSPRUA - 0.282*(ETPFNUA/GOPDUUA) + 35.686*DBCB14		
Rye bio ethanol production	1,000 t	RBSPRUA	RBSPR	RB	SPR	UA	IDEN	RBSPRUA = RYUODUA*RYXTRUA		
Rye bio ethanol imports	1,000 t	RBSMTUA	RBSMT	RB	SMT	UA	IDEN	RBSMTUA = max (0.001, RBUDCUA-RBSPRUA)		
Rye bio ethanol exports	1,000 t	RBUXTUA	RBUXT	RB	UXT	UA	IDEN	RBUXTUA = max (0.001, RBSPRUA-RBUDCUA)		

Fig. 7. AGMEMOD ModelEquations.xls for estimating model

In Fig. 7 the equations of the Baseline scenario are shown. The connections between variables we will show, on the example, equation of the alternative motor fuel price of under constant conditions, that consists of:

$$ETPFNUA = 571.0286 + 0.4194 * GAPFNUA + 0.5375 * GAEMFUA + 0.3759 * FTEMFUA,$$

where ETPFNUA - alternative motor fuel price, UAH/100 kg;
GAEMFUA - gasoline excise duty, UAH/100 kg;
GAPFNUA - gasoline price, UAH/100 kg;
FTEMFUA - alternative motor fuel excise duty, UAH/100 kg.

To assess the adequacy of the econometric model, the following coefficients were calculated using the above packages R:

1. F-test (Fisher's F-test).
2. Using Student's t-distribution to assess the reliability of the correlation coefficient.
3. Testing the model for homo/heteroskedasticity.
4. Checking the factors of the econometric model for multicollinearity.

The model quality test results for some of the equations are shown in Table 1.

The further steps in analyzing the agricultural sector of European countries include modeling of the so-called “what if” scenarios. These scenarios show the impact of various policy measures on policy and the economy as a whole. The practical use of the model and the creation of such scenarios will be described in the next chapter.

Table 1. The model quality test results for some equations of the Baseline scenario

Type of test	p-value				
	ETPFNUA	DZPFNUA	STUODUA	WSUODUA	COUODUA
Shapiro. test of normality	0.83	0.6	0.47	0.36	0.82

Breusch-Pagan test for heteroskedasticity	0.11	0.10	0.11	0.39	0.18
Non-constant Variance Score Test	0.13	0.5	0.37	0.49	0.07
Durbin-Watson Test for Auto correlated Errors (library car)	0.72	0.7	0.82	0.12	0.73
Breusch-Godfrey test for serial correlation	0.11	0.10	0.12	0.25	0.55
Nonlinearity	NO	NO	NO	NO	NO
Residuals vs Leverage - describes the Cook's distance	Normal	Normal	Normal	Normal	Normal
Multicollinearity	FALSE	FALSE	FALSE	FALSE	FALSE

3 The Modelling Results of the Biofuel Market in Ukraine

Proposals and solutions for the Ukrainian biofuel market were generated using GAMS and the endogenous model results were exported to output files. These model output files capture the endogenous projections of development of the biofuel market till 2030 supply and use balances (biofuel production, consumption, imports, exports, and ending stocks) and prices at the country and EU levels. Some of the results are highlighted in Fig. 8.

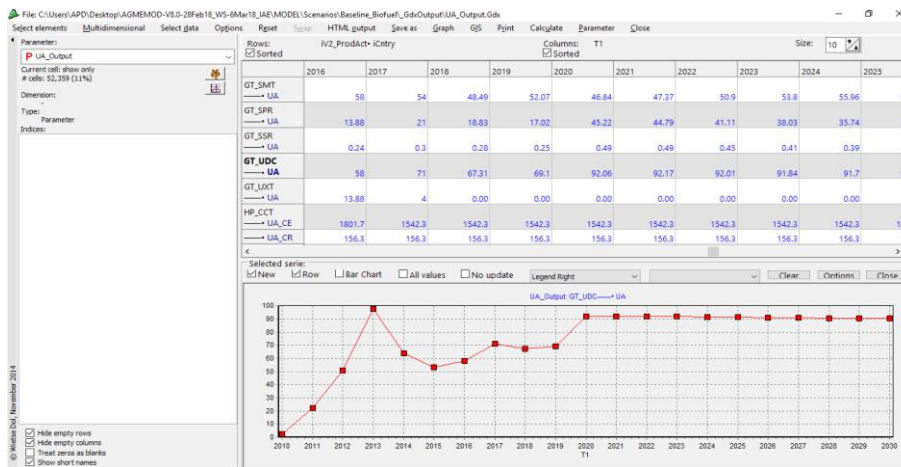


Fig. 8. AGMEMOD results file

It is worth noting that on the graph we can see the slow change in biofuel consumption on the constant condition of the Baseline scenario without any state support which would more sharply influence bioethanol development in Ukraine.

To assess the development of the motor biofuel market (bioethanol, alternative motor fuel, biodiesel), the following scenarios were developed for the achievement of the above-mentioned goals: “Baseline Scenario”, “Policy_10%”, “Direct support_10%”,

“Direct support”, “The Returning excise duty” and “The Cancelling excise duty” that was realized for help creating the following scenarios: “Baseline_Biofuel”, “Biofuel_10”, “Biofuel_Return_Excise” (see above, Fig. 2).

The “Baseline scenario” is based on the assumption that during the projected period 2018-2030, the policy framework conditions in general in Ukraine remain at the 2017 level and the biofuel sector does not receive any state support from 2018 on. It also means that the model considers such factors as conditions of DCFTA as well as other trade regulations, military conflicts in the Donbas region and annexed Crimea, which is excluded from modeling as they were in 2017.

The “Policy_10%” scenario is designed to assess the required level of bioethanol consumption from different crops (wheat, corn, rye, sugar beet) and biodiesel (rapeseed and sunflower oil) based on the performance of the NREAP to determine the amount of bioethanol, alternative motor fuel (hereinafter – AMF) and biodiesel consumption to achieve 10% of biofuels in the total consumption of motor fuels by 2030. According to NREAP, bioethanol (AMF) consumption of 320 ktoe, biodiesel consumption of 70 ktoe should be achieved by the end of 2020.

Taking into account the low level of liquid biofuels production in Ukraine in 2018, achieving these indicative targets is impossible until 2021 without state support. Today in Ukraine there is no direct support and incentives for the production of liquid biofuels and development of the appropriate market. That why we assessed the effect, implementing direct support and tax preferences for bioethanol and biodiesel producers on further biofuel development.

For the analysis of the results of simulation of support scenarios and tax preferences, consideration first was given to changing the price of bioethanol, alternative motor fuel, and biodiesel when introducing each type of support and tax preferences to the biofuels producers concerned. The size of support in the model implemented in the form of price additions in the calculation of UAH per 100 kg of preferential products. Pricing additions are included in the scenario equations, which results in calculating the impact on biofuel production.

The “Direct Support_10%” scenario was designed to assess the implications of introducing a new producer support system in the form of direct subsidies to stimulate and expand biofuel production and achieve 10% biofuel consumption (bioethanol, alternative motor fuel, biodiesel) in total consumption of motor fuels.

To achieve 10% biofuel consumption by the transport sector in the total consumption of motor fuel, the support for bioethanol producers, alternative motor fuel, biodiesel and mixtures based on it was 5500 UAH/100 kg of the finished product. To simulate the state support scenario, this amount of subsidies was calculated as per UAH/100 kg, which is then added to the producer price of the product that is being subsidized and is applied in the equations of the processing model and affects the production and consumption of the product concerned.

By analyzing the modeling results of biofuel domestic use in the “Direct support_10%” scenario, bioethanol domestic use by 2030 will increase from 95 thousand tons to 545 thousand tons (by 5.74 times), for alternative motor fuel - from

90.59 to 538.71 thousand tons (by 5.95 times). It is the best indicator for this scenario. But it can be achieved only with the introduction of direct support to biofuel's producers (Fig. 9).

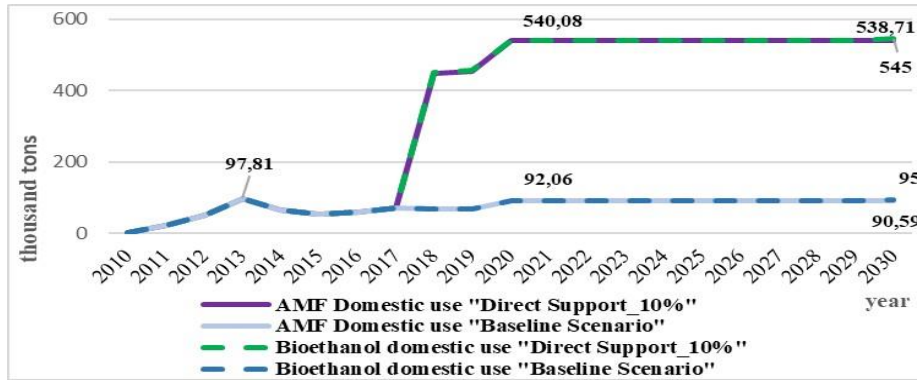


Fig. 9. Bioethanol and AMF domestic use in the “Direct Support_10%” scenario

The “Direct Support” scenario is designed to assess the implications of introducing a new system of direct support for producers, calculated and estimated depending on the expected level of gasoline and diesel consumption by 2030 to meet the needs of consumers in bioethanol, alternative motor fuel and biodiesel in the domestic motor fuel market.

The results of the “Direct Support” scenario indicate that direct support will positively influence the rapid development of the bioethanol sector to meet the needs of the domestic market. As regard bioethanol domestic use will increase from 95 to 180 thousand tons (by 1.89 times), alternative motor fuel - from 90.59 to 170.4 (by 1,88 times) (Fig. 10).

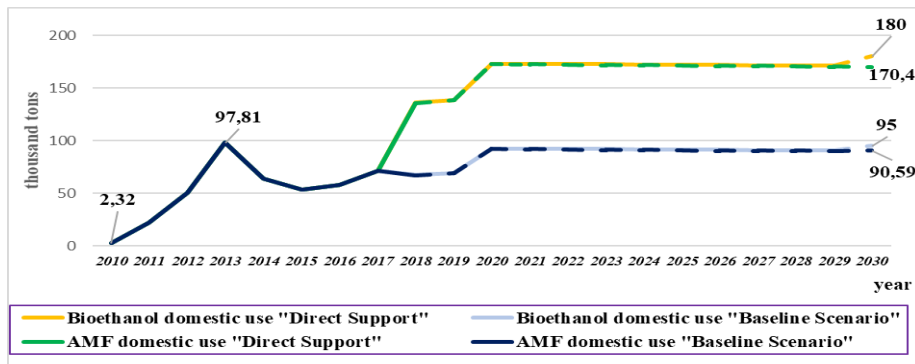


Fig. 10. Bioethanol and AMF domestic use in the “Direct Support” scenario compared to the Baseline scenario

The “Returning excise duty” scenario is designed to assess the implications of introducing a new support system for alternative motor fuels producers and biodiesel producers in the form of returning excise duty to producers from the sales of alternative motor fuels and biodiesel for a year.

The introduction of returning excise duty system for alternative motor fuel producers for sold AMF will stimulate an increase in AMF production, compared to the Baseline Scenario by 3.87 times (from 6.61 to 25.62) and its domestic use in 2030, respectively, will increase by 1.2 times (from 90.59 to 109.72) (Fig. 11). The returning excise duty to producer's AMF for the sector will yield the desired effect and will stimulate expanding production alternative motor fuels.

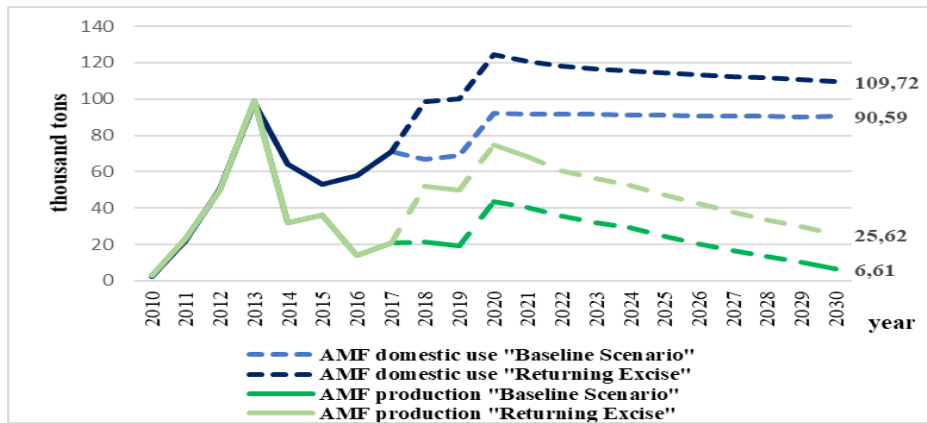


Fig. 11. AMF domestic use and production in the “Returning excise duty” Scenario compared to the Baseline scenario

The “Cancelling excise duty” scenario is designed to assess the consequences of the abolition of the excise duty on the sale of alternative motor fuels and biodiesel produced by these biofuels’ producers. The tool for supporting the development of this sector is the tax exemption for bioethanol and biodiesel as an excisable product. According to the Tax Code of Ukraine, as of 01.11.2018, excise duty on the alternative motor fuel was 130 EUR/1000 kg, biodiesel - 91.2 EUR/1000 kg [23]. If we cancel the above types of excise, the price for producers will have the potential to grow, given the stable demand for these products. For example, the producer's price of alternative fuel motor will increase by 5% in 2030, the producer's price of biodiesel and products based on it will increase by 13.27%.

Besides, the introduction of direct support for producers of liquid biofuels, tax preferences will help producers to increase the production of biofuels, and therefore to achieve the indicative goal of using 10% of liquid biofuels in transport. As follows, for prospering biofuel production in Ukraine has to apply strict well-designed laws, regulations and efficient administrative procedures are necessary that will promote widely development of biofuel production and consumption. Reducing excessive regulations

of biofuel activities will improve the business environment that contributes to increasing the competitiveness and growth of this sector.

4 Conclusions

The paper has highlighted the results of the modelling of the biofuel market in Ukraine until 2030. To achieve the above goals and to quantify the amount of support, an econometric partial equilibrium model was used – AGMEMOD – dynamic model that models the effects of changes in biofuel policy on production biofuels, consumption, imports, exports and biodiesel, and bioethanol prices. For this purpose, was created scenarios of the development of the biofuel market in Ukraine with introduction state support for biofuel producers.

The simulation results of the liquid biofuel market in Ukraine showed that the introduction of state support in the form of direct subsidies to producers of biofuels (scenarios “Direct support_10%”, “Direct support”) and tax preference of state support in the form of a refund of excise duty to producers and the abolition of excise duty on alternative motor fuel and biodiesel scenarios (The “Returning excise duty”, The “Canceling excise duty”) will have a positive impact on the development of all kinds of biofuels in Ukraine. The choice of a particular scenario for the development of the biofuel market or a combination of several scenarios will depend on the possibilities of the state budget, political will, and other factors.

It should be noted that the development of the bioethanol, MTA, biodiesel, and biodiesel based sectors in Ukraine requires both direct support from producers and tax preferences in the form of abolition of excise duty or the return of excise duty on the above products for a certain period to adjust and expand their production, and therefore to achieve the indicative goal of using 10% of liquid biofuels in transport.

The main instruments that contribute to the increase in demand for liquid motor biofuels are the introduction of a mandatory rate of blending biofuels in diesel and gasoline (blending), compliance with the requirements for the share of use of liquid biofuels in Ukraine by 2020 in the total consumption of motor fuels.

But it is worth noting that when conducting the research, we came across with the following limitations of the analysis: many assumptions due to lack of official statistical data, a limited number of observations (throughout 2010-2017), difficulty in the regression’s estimation, and as a result, carefulness in the interpretation of the market simulation results.

The next steps of our research will become the implementation of other biofuel markets (biogas market) in AGMEMOD, statistical estimation of the respective equations; involvement of biofuel market experts (i.e., stakeholders) in the review of simulation results.

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Targeting Model of HEI Video Marketing based on Classification Tree

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Abstract: Modernization of higher education and increased competition in the educational services market require new ways of improving the efficiency of higher education institutions (HEI) management. The generalized structure of forming the HEI video marketing strategy is developed and a series of actions for achieving goals is presented. An algorithm for the targeted advertising forming based on classification tree using R language is proposed. The research methodology is described and HEI targeting model is developed employing the classification tree and contextual advertising campaign data on Facebook. The results of the pilot case study are presented, which confirm the practical usefulness of the proposed targeting model, which allows forming target groups.

Keywords: targeting model, targeted advertising, video marketing, classification tree, dendrogram, Higher Education Institution.

1 Introduction

Today, marketing is a necessary attribute of every higher education institution (HEI). The new Law on Higher Education [28] in Ukraine causes changes in the field of education: the competition between HEIs increases, the requirements and values of consumers (target audiences) have changed significantly. All these factors stimulate the need to organize effective HEI marketing advertising activities. Obviously, a similar problem is relevant for the world education system.

In order to promote education services advertising, HEIs must use modern information and communication technologies, integrated into a well-designed and strategically thought-out system.

One such tool is video marketing, which might be an important part of the overall HEI marketing strategy. For example, recent Ericsson data [13, 14] indicate that world mobile Internet users consume more than half of million gigabytes of mobile data in 2020, and about two-thirds of this amount is used to transmit and download video content. Almost 95% of teenagers have access to smart phones, and 45% of them say they are “almost constantly” on the Internet [12]. A Nielson study [1] shows that performance increases by 74% after 15 seconds of video viewing, and the intention to

make a purchase increases by 72% after 10 seconds of viewing. The number of daily video views on Facebook exceeds 4 billion [15].

Let us give you some statistics on how popular video marketing has become in recent years [36]: video is projected to claim more than 80% of all web traffic; adding a video to marketing emails can boost click-through rates by 200-300%; embedding videos in landing pages can increase conversion rates by 80%; 90% of customers report that product videos help them make purchasing decisions; 87% of online marketers are currently using video content in their digital marketing strategies; a single minute of video content is the equivalent of 1.8 million words.

In this regard, we can assume that the development of HEI marketing strategy should be focused on optimizing the work with the brand, effective use of advertising tools and communication elements, including social networks [34], synthesis of innovative marketing concepts in the field of education [27]. Thus, exploring ways to improve video marketing performance is one of the most promising areas in HEI marketing strategy.

2 Related Work

Paper [33] focuses on the growing importance of online marketing, including research of the state of the art through analysis of the data provided by numerous surveys. It also contains brief description of the online marketing itself, basic strategies on the internet nowadays. The study [22] evaluated the main content of YouTube videos of Spanish brands that were included in the 2015 Interbrand rating. There were estimated 900 videos published by 30 Spanish brands belonging to different business sectors.

The authors [2] have patented that video clips are shown to persons who have a high likelihood of video viewing. When one or more viewers of database saw new videoclip, those viewers who have seen the new clip with positive results are compared to others in the database that have not seen it yet.

The authors [3] have proposed a system and method for providing advertisements targeted at media playlists. The method may include obtaining a user's request for a media item, identification of one or more media playlists. Work [4] proposed a system and method for determining promoter and viewer rewards for video promotion and viewing, including a promoter definition based on matching the profile associated with the video. Article [5] investigates combination of anthropogenic annotated features and general video processing techniques to predict the effectiveness of estimates from Youtube ads.

Paper [6] addresses the problem of video ad performance optimizing with smart technologies that improve the advertising relevance to the target audience. A study [7] describes how to compare at first viewers' reactions to skippable video formats and then to non-skippable formats in terms of recall on brand and economic performance.

The results of the study [8] show that in 2019 digital marketing tools were most actively used: artificial intelligence, augmented reality, machine learning, video marketing, chats, virtual assistants. Article [9] shows which groups of Latin American Facebook users were involved in targeted videos of Hillary Clinton's auto-play during

the 2015/2016 primary election season, which elements in those videos best encouraged these people to like the video.

The purpose of [10] is researching video as potential trigger for consumer behavior. Therefore, the authors applied trigger theory and media to learn about enhancing the effectiveness of mobile marketing videos regarding participants' behavioral intentions. The results show that the consumer's position in the information search was the most important factor. The results obtained in [11] indicate that peripheral ways to persuade have a stronger influence on individual information acceptance than central ways. Paper [16] reviews video crowdfunding activities from the leading crowdfunding website and shows that the proposed measures have an explanatory effect on project financing results.

The attention in [17] is focused on empirical targeting models. The paper argues that the general practice of developing such models does not sufficiently take into account the business goals. The results of a comprehensive empirical study confirm that it is recommended significantly more profitable target groups. Article [25] addresses these issues and provides fresh empirical data on video marketing and its role in nowadays business environment. It also provides insights into video marketing trends and opportunities that are considered crucial in the near future.

The work [18] is the first to investigate the long-term effects of entrepreneurial marketing on social media. Using structural equation modeling, the long-term effect of Facebook-based celebrity endorsement among 234 long-wave Facebook fan community members was also explored. The authors of [19] use content analysis to examine topics and formats of 5932 Facebook posts from leading US colleges and universities. Article [20] combines the substantive characteristics of a short video marketing model with the relevant theories of intention to purchase and propose a research model.

Article [21] examines a technology adoption model to assist the inventor of an online video marketing platform in assessing the behavioral intention to use special online video marketing platforms for small and medium-sized businesses. Article [23] examines the problem of social media marketing of user-created instant music videos. A hybrid variable scale clustering algorithm (HVSC) is proposed to analyze user features using text and video content. A study [24] offers critical managerial perceptions of social media marketing on how to use both FGC and UGC in managing the marketing funnel and brand reputation.

Work [26] analyzed the general evolution of this modern advertising type, which conveys sociocultural values and creates school identity, examines different ways of use, norms, and diversity of the images offered by some educational institutions. The study [30] investigates how to enhance geographical targeting by a suite of other targeting strategies, including behavioral targeting, temporal targeting, and use of discount in an online-to-offline commerce context, to form a more comprehensive contextual targeting strategy. However, there is no specification of this study results.

Work [31] proposes a two-step method based on the Gaussian filter and decision tree (M-GFDT). The Gaussian filter corrects the business data distribution in the first stage, and classifies the decision tree. The decision tree is a widespread approach to identifying and visualizing of logical patterns in data. The decision tree construction

algorithm, first proposed by Quinlan [37], operates on the principle of recursive partitioning of the dataset and incremental tree construction [29].

Multifaceted marketing ads include a look-alike model that reads data on user behavior in networks. For example, in [2] it is patented that video clips are shown to people who have a high likelihood of video viewing, but now Facebook is already doing so during an advertising campaign that simplifies the work [32].

It should be noted the above-mentioned work mostly analyzes user actions in response to video marketing. Besides a number of similar works require relatively sophisticated tools for their implementations, that is, the question of simplifying the formation process and, accordingly, making targeted management decisions in the formation of video marketing strategy is still relevant.

In this regard, a goal of this paper is to develop targeting models for HEI video marketing based on the classification tree (dendrogram). Unlike analogues [30, 31], a model of video marketing targeting based on dendrogram allows making changes by dendrogram branches in the advertising campaign strategy by attributes, which the objective function depends on. Moreover, the use of the *rpart library* in the R programming language makes it possible to clean quickly and filter data, which makes it easier to target groups forming compared to [31]. The novelty of the work is the formation of the most favorable (in economic terms) target group for HEI video marketing, which will reduce the advertising campaign cost.

3 Materials and Methods

3.1 Generalized Algorithmic Structure

Based on the authors' experience in targeting the advertising of the admission campaign and recommendations [33-35], a generalized algorithmic structure for forming HEI video marketing strategy was developed (Fig. 1).

In (Block 1), the HEI determines video marketing strategy for computer science (CS) specialty. Block 2 involves evaluation of the state and potential of the existing HEI CS video marketing, and then strategy objectives are specified (Block 3). In Block 4 planning actions take place. It is necessary to take into account the specificity of HEI advertising, when client's behavior is especially important. Strategy quasi-experiment takes place in Block 5 verifying a proposed strategy in some practical case. Next, we need to evaluate the expected efficiency (Block 6) because it is important for budget redistribution. If this evaluation doesn't satisfy then it is necessary to simulate video marketing targeting for the advertising campaign to make changes during the formation of the target group at the planning stage (Block 4).

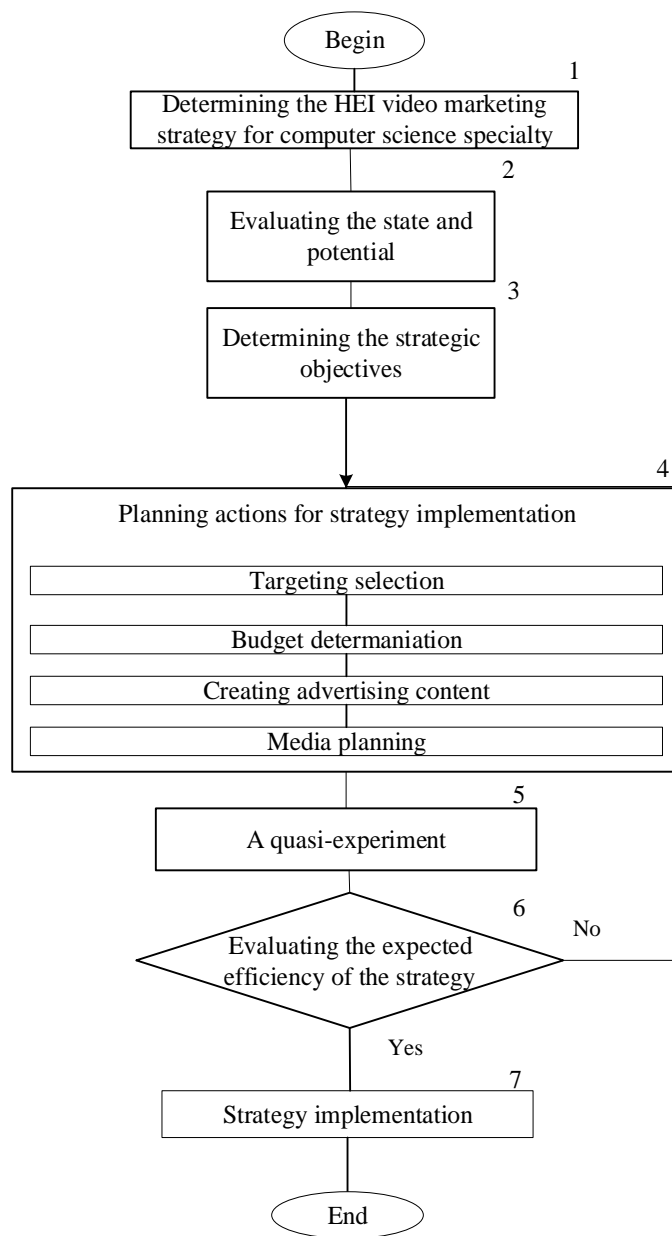


Fig. 1. Generalized algorithmic structure for forming HEI video marketing strategy of computer science specialty

Next, we need to evaluate the efficiency (Block 6) of the expected new video marketing strategy for the computer science specialty, to perform automation at this stage, because it takes a long time to process and is important for budget redistribution.

When evaluating the efficiency of the expected strategy (Block 6), it is necessary to simulate video marketing targeting for the advertising campaign of higher education institutions, which will allow changes to be made during the formation of the target group at the planning stage (Block 4).

3.2 Technique of Experimental Research

Data from Facebook advertising campaign results are used as a basis for the experimental research methodology. As mentioned above, HEI targeted advertising should be focused on customer behavior. Therefore, in the first step of the technique, it is advisable to select the following four targeting options for *Age*, *Sex*, *r*, *Vaverage* (Table 1).

Table 1. Video marketing targeting options for Facebook advertising campaigns

Parameter	Indicator	Description
<i>Age</i>	Age	Age groups: 13-18, 18-25, 25-30, 30-35, 35-40, 40-45, 45-50, 50-55
<i>Sex</i>	Sex	female, male
<i>r</i>	Results	The number of times, when ad has reached a goal-specific result and setting.
<i>Vaverage</i>	Average video watching time	The average video playback time, including the retry time of a single show.

The next step in the technique is to target Facebook video advertising. For this purpose, it is expedient to employ an algorithm for recursive partitioning of a data set and incremental construction of a tree [29, 37]. To assess the quality of the constructed tree T during its optimization, the following set of criteria is used:

- penalty for model cost complexity, which includes a penalty factor for each uncut branch $CC(T = \sum tDt + \lambda t)$;
- deviation $D0$ for the zero tree (i.e. variability estimation in the original data);
- relative parameter of value complexity $Cp = \lambda/D0$;
- relative learning error for a tree with t nodes $RELER = \sum tDt/D0$;
- cross-check error ($CVerCVer$) with a breakdown of 10 blocks, also attributed to the zero-tree deviance D_0 ; $CVer$, is usually larger than $RELER$;
- standard deviation (S_i) of the cross-check error.

Preferred is a tree consisting of such a number of branches t for which the sum ($CVer + SE$) is minimal.

Hence, an algorithm (Fig. 2) was developed based on dichotomous trees [29], implemented in the programming language R.

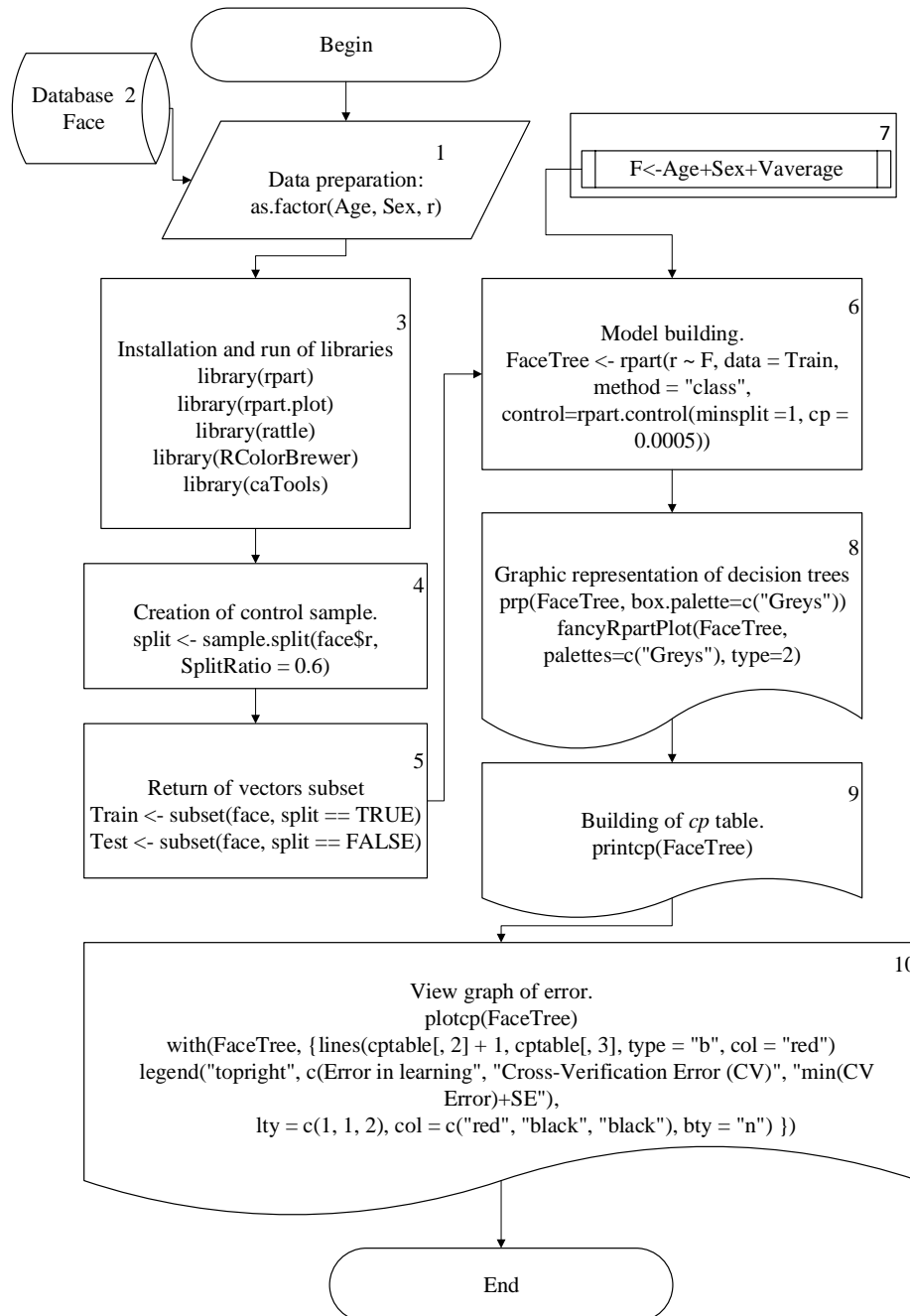


Fig. 2. Algorithm for targeting video marketing based on dendrogram using R language

In block 1, the data must be prepared and cleared for analysis (file with the extension “*.xlsx”) (block 2), where the model parameters values are located in columns. Parameters are converted into data with factors value of (*Age*, *Sex* and *r*).

Next, the libraries (Block 3) are run to build the model, control samples (Block 4) are created and the vector *r* data is split into two groups in a predetermined ratio, keeping the relative ratios of different labels in *r*. In addition, a subset (Block 5) of vectors, matrices, or data frames that meet certain conditions are returned. In block 6, a targeting model is constructed based on the recursive partition and regression tree, taking into account the settings (Block 7) and the graphical representation of the dendrogram (Block 8). Block 9 builds a *cp* table based on the tree Complexity Parameter, and block 10 maps the model errors, details of which are described below in Section 3.3.

3.3 Experimental Results and Discussion

For implementation of the algorithm and the program (see Fig. 2) on the example of the admission campaign for “Computer Science specialty” of Ternopil National Economic University (Fig. 3) more than a thousand of indicators of advertising campaign on Facebook according to the parameters (see a Table 1) were used.

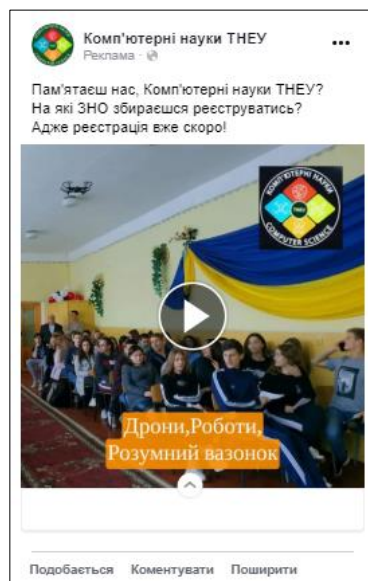


Fig. 3. Targeted Computer Science advertising at Ternopil National Economic University on Facebook

The resulting model of targeting based on dendrogram is presented in Fig. 4 and a graphical representation of the model error is in Fig. 5. As it can be seen in Fig. 4 most videos were viewed by male clients in the age of 18-25, 35-55.

The ordinate axis (see Fig. 5) shows the X-val Relative Error and the abscissa axis parameter of the complexity of the tree cp , which starts from the lower boundary point (inf). Size of tree is determined by the number of branches 1... 9. As it can be seen in Fig. 5, starting from branch 7 of the tree the result is stabilized and the subsequent addition of branches has little effect on the tree learning error.

The calculations showed that the parameter of the tree complexity, with a minimum of relative error (min (SV error) + SE) at cross-checking is determined by the value of $cp = 0.0033$ between branches 7 and 8 (see Fig. 5), where SV is Cross Validated and SE – Standard Error for cross validation error.

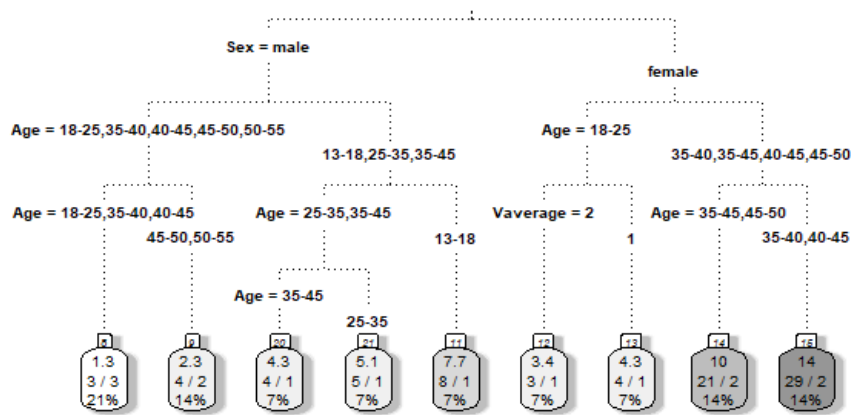


Fig. 4. Targeting tree-based model for HEI solutions

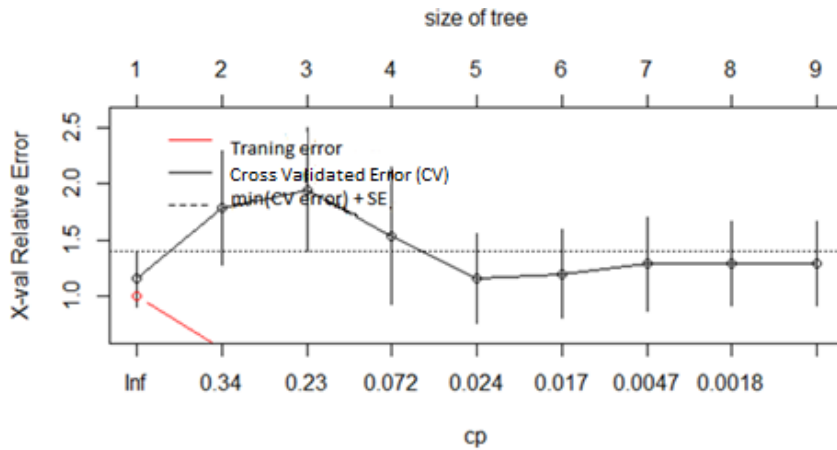


Fig. 5. Error graphical representation of the targeting model based on dendrogram

To check the modeling results based on dendrogram (see Figs. 4, 5), a repeated simulation of targeted advertising was conducted, where we select the following target group for the ad: male in the age group 18-25, 35-55. As can be seen from the results of the re-simulation (Fig. 6), the conversion cost for video ads decreased from \$ 0.99 to \$ 0.08 as of July 13, 2019 (with 113 conversions), which is about 24% better than the first ad variant campaigns.



Fig. 6. The results of the re-simulation on Facebook

Let's keep in mind that the average of an ad is click-through rate – *CTR* increased from 2.78 to 3.4.

Unlike analogues [30, 31], the Targeted advertising model, based on dendrogram, allows the tree branches making changes in the advertising campaign strategy for the attributes, which the target function depends on. Moreover, the use of *rpart* library in the R programming language makes it possible to quickly clean and filter data, which simplifies the formation of target groups compared to [31].

4 Conclusions

A generalized algorithmic structure for HEI video marketing strategy forming is proposed, which is focused on Targeted Advertising, to improve the effectiveness of the admission campaign.

A targeting model based on dendrogram and target group allocation has been developed, which allows using tree branches to make changes in advertising campaign strategy based on the attributes dependent on the target function. Moreover, the proposed targeting model makes it possible to quickly clean and filter data, which simplifies targeting.

The results of the experimental research conducted on the example of HEI admission campaign for computing major confirmed the effectiveness of the developed targeting model, which is of practical importance in the formation of the Targeted Advertising budget, as part of the formation of video marketing strategy.

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Identifying the Gaps in the Preparing of a Business Analyst between the Requirements of the Labor Market and the Standards of Study Programs: Case of Ukraine

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Abstract. Efficient human resource management needs accurate assessment and representation of available competences as well as effective mapping of required competences for specific jobs and positions. Thus, definition and identification of competence gaps express differences between acquired and required competences using a mathematical approach to support accurate competence analytics. Lack of skills and insufficient qualifications of employees are cited as major barriers to the adoption of new technologies in the context of Industry 4.0. These changes require skills for data analytics tasks. The purpose of this paper is to investigate gaps in the preparing of a business analyst between the requirements of the labor market and the standards of study programs. For the IT and other industries, the most important competencies from study program of Ukrainian High Educational Institutes, which correspond to labor market requirements, were revealed using RStudio.

Keywords. IT Education, Business Analyst, Generic Competencies, Subject Specific Competencies, Study Programs.

1 Introduction

The European Higher Education Area promotes the design of curricula focused on the acquisition of competences. Efficient human resource management needs accurate assessment and representation of available competences as well as effective mapping of required competences for specific jobs and positions. Thus, definition and identification of competence gaps express differences between acquired and required competences using a mathematical approach to support accurate competence analytics. Lack of skills and insufficient qualifications of employees are cited as major barriers to the adoption of new technologies in the context of Industry 4.0. These changes require skills for data analytics tasks. Business analytics (BA) becomes increasingly important under rapidly changing business environment. It requires conceptual model for the professional profile of a Data

Scientist in the field of Information and Communications Technology (ICT), namely in the European e-Competence (e-CF) framework and the Skills Framework for the Information Age (SFIA) are related with ICT competences/skills, including programming, machine learning and databases. The Data Scientist professional profile combining contributes from different areas, such as computer science, statistics and mathematics. To analyze impact of competences on employment we subcategorized competencies into generic and specific subject competencies for different job types.

The results show that data management capability fully mediates between IT competence and BA use. The paper analyses how individual job competences requirements impact on wage changes.

The purpose of this paper is to investigate gaps in the preparing of a business analyst between the requirements of the labor market and the standards of study programs.

The remainder of our paper is organized as follows: in section 2 we analyze Ukrainian IT market and the imbalance of quality in the IT labor market in Ukraine. In section 3, we present and discuss experimental model where we investigates specific subject competences from high education institutes of Ukraine which significantly impact on average wage of a business analyst. Finally, last section concludes.

2 Related works

2.1. Ukrainian IT market

Ukrainian IT market is actively growing and developing over the past few years. It has reached the point of 3.473 USD billion, which is 3.9% of GDP and 22% of service export in 2018. According to IT Ukraine Association estimation, export of IT services grew by 30.2% in 2019 and tot up 4.17 USD billion, and got the better of the traditional product for Ukrainian export – wheat, becoming second export industry [1] and the largest exporter of IT services in Europe [2] (fig. 1). Moreover, according to UNIT.City forecast, Ukrainian exports of IT services will be \$5.4 billion in 2020 and \$8.4 billion in 2025 [2].

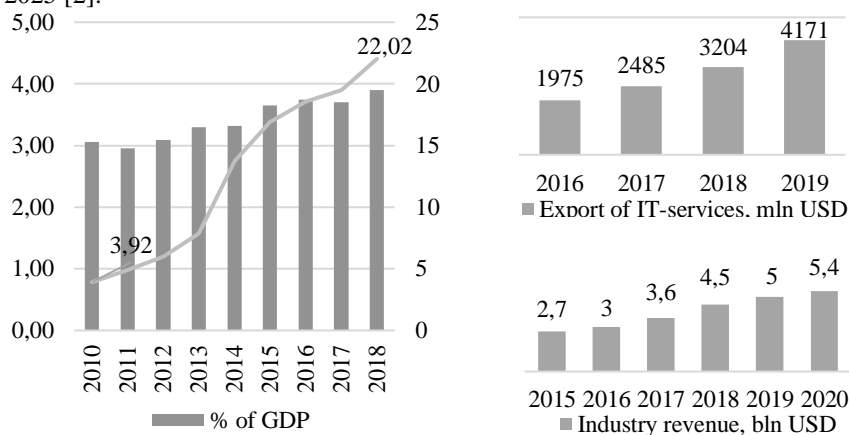


Fig. 1. Dynamics of IT sector development in Ukraine [1,4,5]

According to IT Outsourcing News, Ukraine became the first country in Europe within IT outsourcing and software development in 2016 [5] and is still the first outsourcing market in Eastern Europe [6] (fig. 2). In 2017-2018 Ukrainian and with Ukrainian roots companies and startups made 44 deals for a total of \$265 million, namely Gitlab (\$130 million), Grammarly and BitFury (\$110 million everyone). Unit.City also ranked the most promising Ukrainian startups, such as People.ai, monobank, Allset, Solar Gaps and Kwambio [2].



1 place in Europe in terms of the volume of IT service exports

- 7 place in the world in terms of quality and efficiency of the freelance workforce
- 8 place in the world's top countries with the best programmers by SkillValue
- 11 place in the top 50 world's developers
- 20 in A. T. Kearney Global Services Location Index of the most attractive outsourcing destinations
- 24 place among the 55 most attractive countries
- 43 out of 126 countries in 2018 according to the Global Innovation Index

Fig. 2. Rating position of Ukraine at global IT market [2; 6; 7]

Ukrainian outsourcers cooperate mainly with parties from the USA (fig. 3), including worldwide-known companies, such as Cisco, IBM, Atlassian, Travelport, OpenText, Fluke Corporation, etc [7]. However, operations with European businesses, mainly from the UK and Germany, have grown significantly over the years as well [8].

The key areas of domestic IT specialization are: data management, telecommunications, cloud, gaming, e-commerce, media, fintech, healthcare, and others (fig. 4) [9; 10].

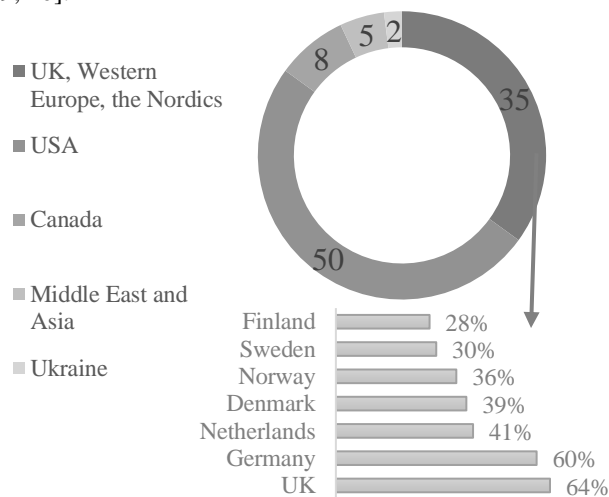


Fig. 3. Geographical structure of IT services export, % [9; 10]

Key factors of the rapid growth of Ukrainian IT sector in the recent years include [12]: stable tax policy; the refusal of regulatory barriers; Ukrainian brand promotion at the international market; and the most important, talent pool and advanced IT education, which, however, is on the verge of a structural crisis. For instance, World Economic Forum named Ukraine among the top 10 countries globally by the number of engineering, manufacturing, and construction graduates [6].

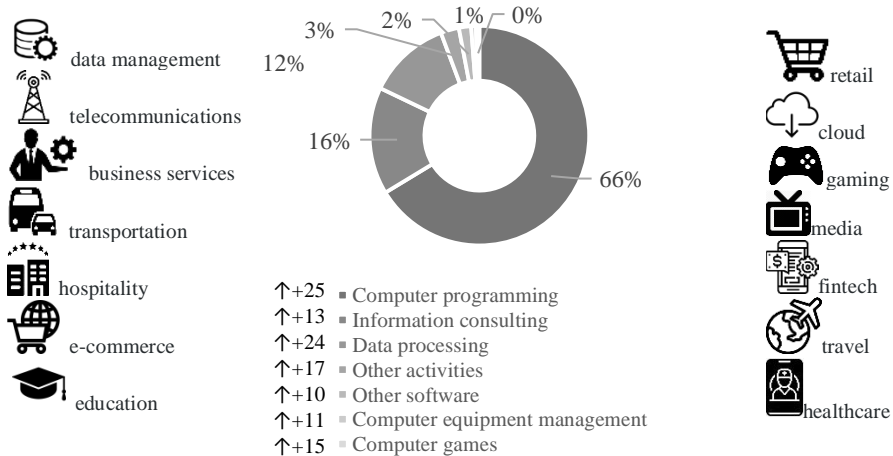


Fig. 4. Structure of services of the domestic IT sector [11]

Highly developed education and the increase of demand for IT services have led to the rapid growth of specialists in this field in the domestic market (fig. 5). According to the Ukrainian IT-company N-iX, in 2018 this number has already reached 184-185 thousand people, and according to estimates will reach 200 and 220 thousand people in 2019 and 2020, respectively [6; 7].

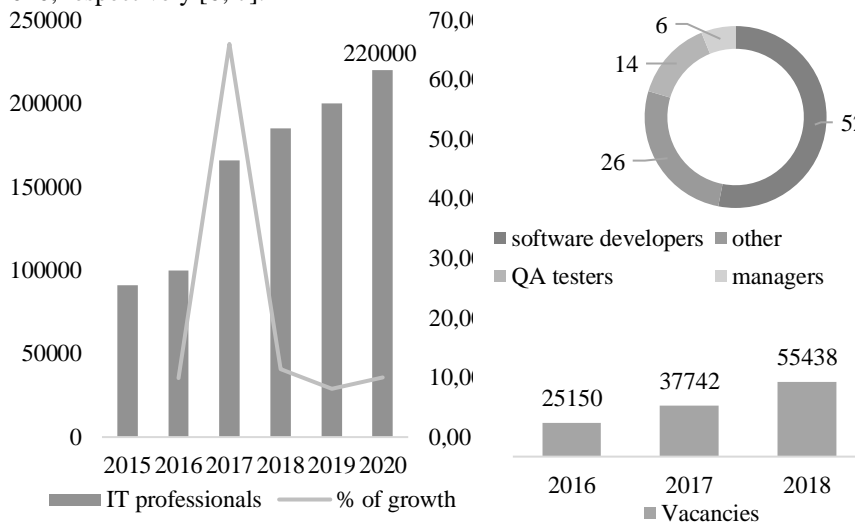


Fig. 5. The IT labor market in Ukraine [7]

However, despite the supply steadily climbs, it can not meet the demand for IT professionals and it has created a quantitative imbalance in the labor market - 23,000 annual graduates from IT majors at more than 150 universities, unable to meet existing demand in more than 55 thousand job places [13].

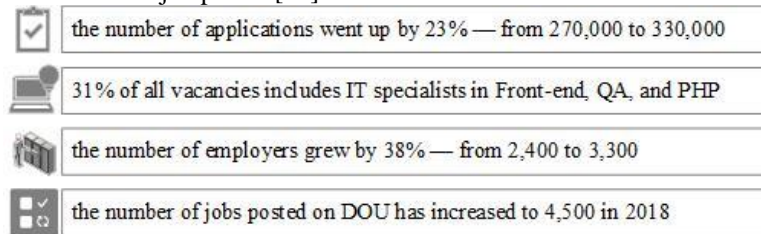


Fig. 6. Key parameters of the Ukrainian labor market within IT industry in 2018 [7]

Moreover, the qualifications of current employees do not meet the requirements of the modern labor market. It makes IT companies spend resources on additional training and retraining of their staff. The reason for the quality imbalance is the gap between educational components of educational programs and real requirements of employers to the professional competencies of students and graduates, which are verified during their first job interview.

2.2. The imbalance of quality in the IT labor market in Ukraine

Based on a survey of 8,638 questionnaires of IT sector workers, a portrait of a modern Ukrainian IT specialist was drawn up. Thus, 87% of women and 82% of men working in this field, have higher education. It is interesting to note that 58% of women and 64% of men, who hold technical positions, have higher field-specific education [14]. Moreover, IT majors are also popular among second higher education students. “Information Systems” is becoming more and more popular in recent years [15].

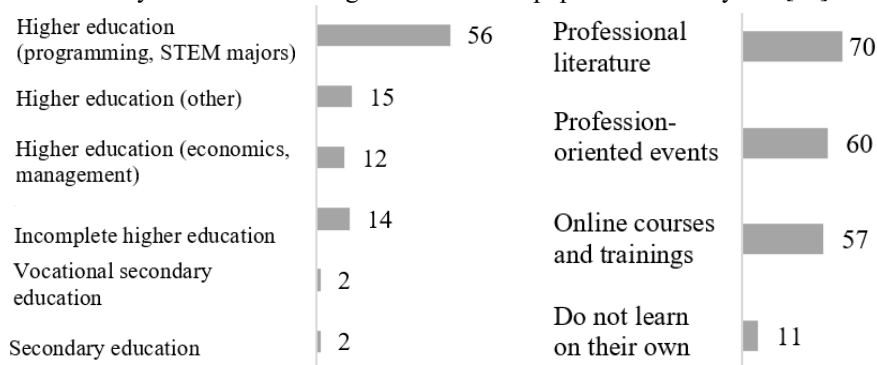


Fig. 7. Types of formal and non-formal education of IT specialists, % [14]

However, the interest in higher education within technical majors (especially at the second level degree) gradually declines. The reasons are: the irrelevance of some

educational components and neglecting of the diploma importance in the real labor market. Consequently, formal education hands to work experience and non-formal /informal education guaranteeing certificates, which are usually more significant for employers to compare with a prestigious university diploma. In long term orientation, this tendency hides the risk to tear down fundamental basics of training of specialists within technical majors at classical universities, in favor of professional or informal trainings. As a result, universities can transform into a networking platform rather than being an educational providers. For instance, a common report of the Western NIS Enterprise Fund and UNIT.City on the topic of IT ecosystem in Ukraine profiles 7 leading universities within technical majors and 18 IT courses and schools. Moreover, the general number of students in IT courses and schools is 46.5 times bigger than at universities.

In 2018, 10% of employed and hired people in the Ukrainian IT sphere did not have a university diploma [16]. According to HeadHunter, around 56% and ITUkraine Association - 36% of domestic IT professionals do not have university diploma and this indicator is gradually increasing both in Ukraine and all over the world [17]. Apple CEO Tim Cook has officially stated that half of the 2018 hires do not have a college degree because most colleges do not teach their students skills which are required by large corporations [17]. In spite of old mathematical and IT schools, historically formed in Ukraine, modern systems of secondary and higher education in Ukraine are focused more on the acquisition and reproduction of fundamental knowledge, rather than skills and competencies: professional (ability to solve case studies), as well as soft skills (communication, presentation, organizational, teamwork), which are priorities for employers when being hired. Consequently, the government spends resources irrationally to teach future specialists, while business has been preparing their corporate roster for 3-6 months before hiring (table 1).

Table 1. Institutional support for IT education in Ukraine [13]

#	Formal education		Nonformal education					
	Institutions	Students	#	Institutions	Students	#	Institutions	Students
1	Kharkiv National University of Radio Electronics	2,968	1	Blockchain-Hub Academy	30	10	Main Academy	6,000
2	Lviv Polytechnic National University	2,675	2	BrainBasket Foundation	6,000	11	Projector	1,500
3	National Technical University of Ukraine "Ihor Sikorsky Kyiv Polytechnic Institute"	4,314	3	CyberBionic Systematics	3,000	12	Prometheus	700,000
			4	GoIT	2,000	13	QALight	8,000
4	National Technical University "Kharkiv Polytechnic Institute"	2,105	5	"STEP" computer academy	95,000	14	Sigma Software University	600
5	National University "Kyiv-Mohyla Academy"	3,500	6	UNIT Factory	900	15	Ukrainian IT School	1,600
6	Taras Shevchenko National University in Kyiv	1,324	7	ITEA	11,000	16	SkillUP	18,850
			8	uData Schoo	90	17	iTalent	6,000
7	Zhukovsky National Aerospace University "Kharkiv Aviation Institute"	1,692	9	LITS (Lviv IT School)	2,000	18	SoftServe IT Academy	1,600
<i>SUM</i>		<i>18,578</i>	<i>SUM</i>					<i>864,170</i>

Thus, in order to meet the current challenges of the labor market, IT representatives are

forced to actively engage in self-education mostly aimed at learning foreign languages (often English) and developing soft skills through psychological and management trainings (most often in time management, team-building, leadership, project management, promotion, marketing) rarely in hard skills (different programming languages) [15.]. Sufficient system of motivation for the IT work based on an assessment of their competence level should be a tool for solving the problems of IT education development [18].

In 2015, the reform of higher education in Ukraine began. It was aimed at acquisition competencies - Generic Competencies, closely connected with soft skills, and Subject Specific Competencies.

To investigate the gap between the quality of higher education and the requirements of employers, we have selected a job position “Business Analyst”. Both IT specialists and economists with analytical thinking and basic knowledge of programming can apply for this position (fig. 8). As a consequence, graduates of three majors are able to work as business analysts: systems analysis (124), economics (051, specialization: economic cybernetics) and information systems and technologies (126).

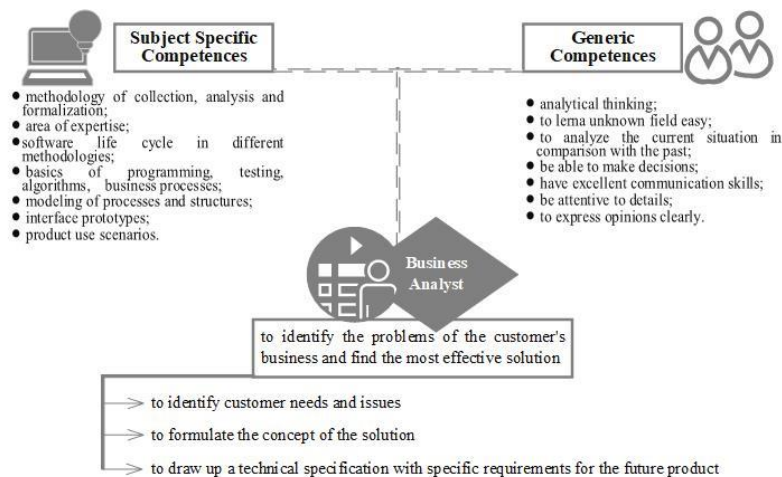


Fig. 8. Basic characteristics of a business analyst

3. Experimental Model

Higher education institutions in business analysts training should develop an educational program and frame educational process to form generic (GC) and subject specific Competencies (SC) of graduates in a line with standards of the Ministry of Education and Science of Ukraine in System Analysis (124), Economics (051, economic cybernetics), Information Systems and Technologies (126) [19].

We have carried out a comparative analysis of generic and subject specific competencies according to the Ministry of Education and Science of Ukraine for majors 051, 124, 126 essentials to become a business analyst. As a result, we obtained 18 common generic (Table 2) and 22 common subject specific competencies (Table 3).

Table 2. Generic Competencies of Business Analyst by higher education institutions

№	Generic competencies for Business Analyst
1	Ability to be critical and self-critical
2	Ability to learn and become proficient in modern knowledge
3	Ability to generate new ideas (creativity)
4	Ability to act socially responsible and consciously
5	Ability to abstract thinking, analysis and design
6	Ability to adapt and act in a new situation
7	Ability to search, process and analyze information from various sources
8	Ability to apply knowledge in practical situations
9	Ability to evaluate and ensure the quality of work performed
10	Ability to plan and manage time
11	Ability to work independently
12	Ability to work in a team
13	Ability to make informed decisions
14	Ability to develop and manage projects
15	Ability to communicate in the official language orally and in writing
16	Ability to communicate in a foreign language and work in an international context
17	Information and communication technology skills
18	Interpersonal skills

Table 3. Subject specific competencies of Business Analyst by higher education institutions

№	Subject specific competencies of a Business Analyst
1	Ability to identify knowledge and understand the problems of the subject area, the basics of the modern economy at the micro, meso, macro and international levels.
2	Ability to explain economic and social processes and phenomena through theoretical models, to analyze and interpret the results.
3	Ability to formalize problems described in natural language, through mathematical methods as well, to apply common approaches to mathematical modeling of specific processes.
4	Ability to build correct models of static and dynamic processes, and systems with distributed and lumped parameters, taking into account the uncertainty of external and internal factors.
5	Ability to use modern information technology to implement machine-assisted realization of mathematical models and predict behavior of specific systems, namely: object-oriented approach in the design of complex systems of different types, applied mathematical packages, use of databases and knowledge.
6	Ability to identify the main impact factors of the development of physical, economic, social processes, pick out stochastic and indeterminate indicators, formulate them in random or fuzzy quantities, vectors, processes and to study the dependencies between them.
7	Ability to analyze and design complex systems, create relevant information technologies and software.
8	Ability to design experimental and observational studies and analyze the results.
9	Ability to analyze, synthesize and optimize information systems and technologies using mathematical models and methods.
10	The ability to perform simulation experiments, to compare the results of experimental data and the solutions obtained.
11	Ability to use computer technology and data processing software to solve economic problems, analyze information, and prepare analytical reports.
12	Ability to analyze and solve problems in the field of economic and social-labor relations.
13	Ability to predict socio-economic processes based on standard theoretical and

	econometric models.
14	Ability to use modern sources of economic, social, management, accounting information to prepare official documents and analytical reports.
15	Ability to conduct economic analysis of the operation and development of business entities, assess their competitiveness.
16	Ability to identify economic problems in the analysis of specific situations, to offer ways to solve them independently.
17	Ability to formulate optimization problems in the design of systems of management and decision making, namely: mathematical models, optimality criteria, constraints, management goals, choose rational methods and algorithms for solving optimization and optimal management.
18	Ability to apply information technologies to create, implement and utilize quality management system and estimate the costs of its development and maintenance.
19	The ability to manage the quality of products and services of information systems and technologies throughout their life cycle.
20	Ability to develop business decisions and evaluate new technology offers.
21	Ability to manage and use modern information and communication systems and technologies (including Internet based).
22	Ability to create new competitive ideas and implement them in projects (startups).

We have analyzed the general requirements of employers for the competencies of applicants for the position of the business analyst on the sites for job search: work.ua, rabota.ua, djinni.co, linkedin.com, hh.ua, it-stars.ua, jobs.ua. Then, we have compared them with standards of the Ministry of Education and Science of Ukraine (tables 2 and 3). As a result, we identified generic (table 4) and subject specific (table 5) competencies common both for the labor market and higher education institutions.

Table 4. Common generic competencies of a Business Analyst for higher education institutions and labor market

GC	GC by higher education institutions	GC by labor market
GC1	Ability to learn and become proficient in modern knowledge	Desire to learn
GC2	Ability to generate new ideas (creativity)	Creativity
GC3	The ability to act socially responsible and consciously	Responsibility
GC4	Ability to abstract thinking, analysis and design	Analytical and logical thinking, systems thinking
GC5	Ability to search, process and analyze information from various sources	Attention to Detail
GC6	Ability to apply knowledge in practical situations	Problem Solving
GC7	Ability to plan and manage time	Time Management
GC8	Ability to work in a team	Teamwork
GC9	Ability to develop and manage projects	Organizational skills
GC10	Ability to communicate in a foreign language and work in an international context	English skills
GC11	Information and communication technology skills	Presentation Skills
GC12	Interpersonal skills	Communication
GC13	NA*	Self-motivation

*NA – not announced

Table 5. Common subject specific competencies of a Business Analyst for higher education institutions and labor market

SC	SC by higher education institutions	SC by labor market
SC1	Ability to explain economic and social processes and phenomena through theoretical models, to analyze and interpret the results.	Development of use-cases and user-stories
SC2	Ability to formalize problems described in natural language, through mathematical methods as well, to apply common approaches to mathematical modeling of specific processes.	Requirements collection, negotiations with stakeholders, UML/BPMN
SC3	Ability to use modern information technology to implement machine-assisted realization of mathematical models and predict behavior of specific systems, namely: object-oriented approach in the design of complex systems of different types, applied mathematical packages, use of databases and knowledge.	Hands-on experience with data visualization via reports and dashboards, Flow charts, Lucidchart MS Access, MS SQL Server, Oracle
SC4	Ability to analyze and design complex systems, create relevant information technologies and software.	Experience in the development of technical documentation, requirements, software development processes (UML, Use Cases, Business Rules, Functional Non-Functional Specifications, User Interface Design Specifications, User Stories, Backlogs)
SC5	Ability to analyze, synthesize and optimize information systems and technologies using mathematical models and methods.	Information systems
SC6	The ability to perform simulation experiments, to compare the results of experimental data and the solutions obtained.	Data analysis, Database Management System, DBMS
SC7	Ability to use computer technology and data processing software to solve economic problems, analyze information, and prepare analytical reports.	BA techniques (interview, workshop, document analysis, estimation, mind mapping, etc)
SC8	Ability to use modern sources of economic, social, management, accounting information to prepare official documents and analytical reports.	Management accounting, corporate finance and financial statements / IC
SC9	Ability to formulate optimization problems in the design of systems of management and decision making, namely: mathematical models, optimality criteria, constraints, management goals, choose rational methods and algorithms for solving optimization and optimal management.	Algorithms, data structures, client-server application architecture, web application architecture, service-oriented architecture (SOA)
SC10	Ability to apply information technologies to create, implement and utilize quality management system and estimate the costs of its development and maintenance.	CRM
SC11	The ability to manage the quality of products and services of information systems and technologies throughout their life cycle.	Project management, Software Development, Software Development Life Cycle and MVP
SC12	Ability to develop business decisions and evaluate new technology offers.	Business processes modeling, MS Visio
SC13	Ability to manage and use modern information and communication systems and technologies (including Internet based).	MS Access, MS Excel, MS Power Point
SC14	Ability to create new competitive ideas and implement them in projects (startups).	JIRA Confluence, MS Project
SC15	NA*	Understanding of agile development processes (e.g. Scrum, SDLC, Kanban)

*NA – not announced

Based on open Internet sources of websites for job search, a data set of 118 vacancies for the position of the business analyst was created. This data set includes the

name of the employer, vacant position the average salary and required generic and subject specific competencies (Table 6).

Table 6. Vacant position profile of business analyst competencies on the labor market

№	Employer	Position	Wage, \$	GC1	...	GC13	SC1	...	SC15
1	IT Specialist, Ltd	System analyst	35000	0	...	0	0	...	0
2	INNOWARE	Junior Business Analyst	35000	0	...	1	0	...	0
3	Proxima International	Business Analyst	50225	0	...	0	0	...	0
4	Betinvest Ltd	Business Analyst	18000	0	...	0	0	...	1
5	Linkos Group	System analyst	18000	0	...	0	0	...	0
6	Deep Consulting Solutions	Business Analyst	36000	1	...	1	0	...	0
7	PMLAB	Data/Business Analyst	44000	0	...	0	0	...	0
8	Paymentwall	Business Intelligence Analyst	35000	0	...	0	0	...	0
9	EPAM / Eepam Systems	Senior Business Analyst	31000	1	...	0	0	...	0
...
118	Lifecell	System analyst	30000	0	...	0	0	...	0

All vacancies can be classified by following industries: IT consulting (48), Banks (23), Retail (12), Government Institution (6), Others (29) (include mobile operators, agriculture, oil, etc.).

To determine the relevance of the impact of generic and specific subject competencies on the average wage, we consider a multiple regression model:

$$w_i = b_0 + \sum_{j=1}^{13} GC_j + \sum_{k=1}^{15} SC_k + u_i \quad (1)$$

where w_i – average wage for a job i , GC_j – generic competence j , SC_k – specific subject competence k , u_i – error term.

```
f <- read.csv("HEI and LM.txt", sep="\t", header=TRUE,
dec=".")
model1 <- lm(data=f, Wage~.)
summary(model_1)
f2<- read.csv("IT consulting.txt", sep="\t",
header=TRUE, dec=".")
model2 <- lm(data=f2, Wage~.)
summary(model2)
```

It has been obtained that by sampling of all positions of business analysts:

- 1) use of information and communication technologies or Presentation Skills (GC11) can increase the average monthly wage by +\$9361.9;
- 2) the ability to apply knowledge in practical situations or Problem Solving (SC6)

causes an average wage increasing on \$10009.

Table 7. Statistically significant Competencies for the labor market

Model	Explanatory Competencies	Marginal effect of parameters (\$)	R ² (%)
All	GC11	+9361.9	22,56
	SC6	+10009	
IT consulting	SC8	+23376	23,83
	SC14	-9062	
Banks	NA	NA	NA
Retail	NA	NA	NA
Others	SC13	+29896	87,3
	SC14	+36683	

Among BA job applicants with GC11 competence, only 10% have SC6 specific subject competence simultaneously, and vice versa: if a candidate has SC6 competence, only every tenth has GC11 competence (fig. 9):

```
mosaic(data=f, ~GC11+SC6, shade=TRUE)
```

For the IT industry, the most important competencies were revealed as follow:

1) SC8 Management Accounting, Corporate Finance and Financial Statements / 1C determined an average monthly wage increase of +\$23376;

2) SC14 The ability to form new competitive ideas and implement them in projects (start-ups) for graduates does not meet the requirements of the IT industry (JIRA Confluence, MS Project), and therefore leads to a decrease in salary by \$9062, which confirms the lack of competence in the HEA.

Among BA job applicants with SC8 competence, only 20% have SC14 specific subject competence at the same time. If the applicant has SC14 competence, only 10% have SC8 competence. Among BA job applicants with GC11 competence, only 10% have SC6 specific subject competence, and vice versa: if a candidate has SC6 competence, only every tenth has GC11 competence (fig. 10):

```
mosaic(data=f2, ~SC8+SC14, shade=TRUE)
```

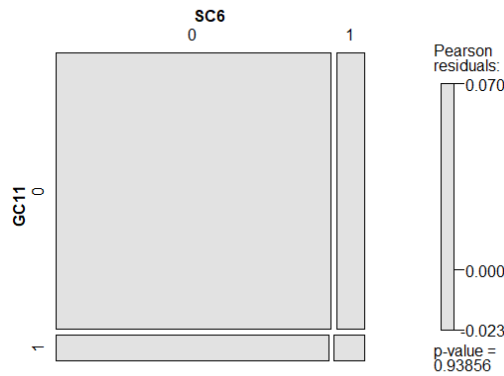


Fig. 9. Relationship between GC11 and SC6 competencies

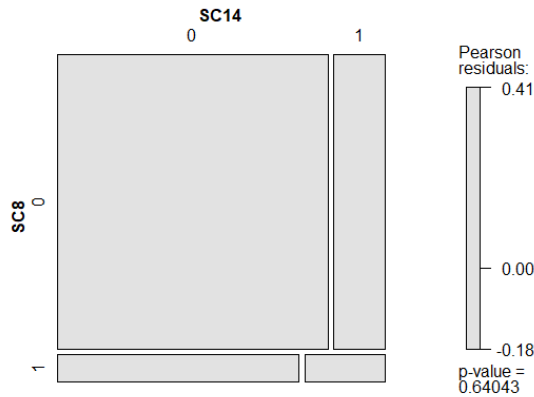


Fig. 10. Relationship between SC8 and SC14 competencies

As well as if the applicant has SC8 competency for the BA vacancy, his/her average wage remains lower than in the case of other competencies required:

`g2 + facet_grid(SC8~SC14)` (fig. 11)

`gg0 + stat_smooth(method="lm") + facet_grid(~SC14)` (fig. 12)

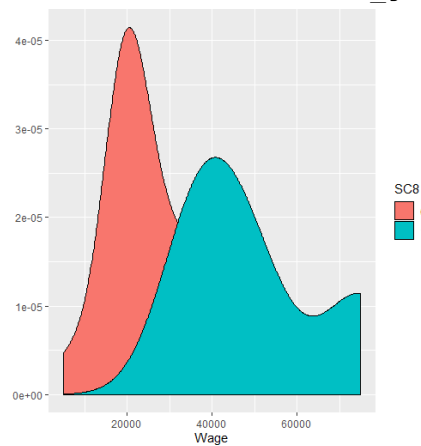


Fig. 11. Wage distribution for SC8 competence

SC8's competence slightly increases the average wage, while in its absence the wage increases much faster. Therefore, the skills of an accountant in the labor market are worth much less than the skills of a business analyst (fig. 12).

For other positions not covered by IT consulting, Banks Government Institutions, the most required competencies were revealed:

1) SC13 Ability to manage and use state-of-the-art information and communication systems and technologies (including Internet-based ones, MS Access, MS Excel, MS Power Point) adds +\$29996 each month;

2) SC14 The ability to form new competitive ideas and implement them in projects (startups), JIRA Confluence, MS Project proves that this competence is formed for

other industries and raises wages by an average of \$36683.

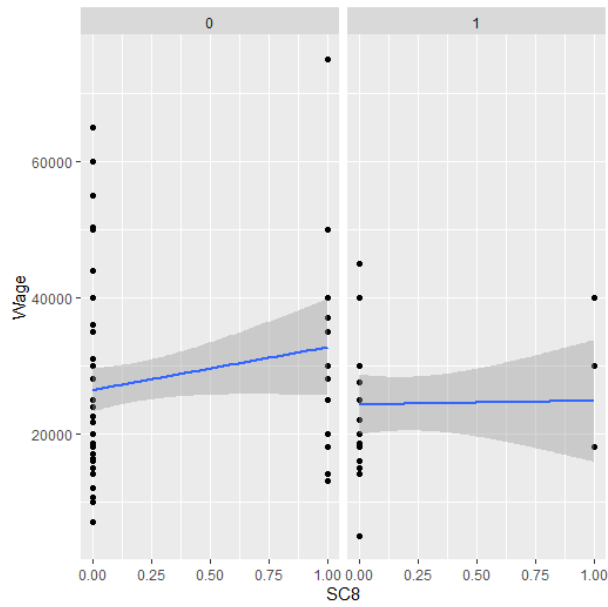


Fig. 12. Wage dynamics in the absence and availability of SC8 competence

Thus, the wage distribution is set out as follows (fig. 13), where the average wage per year is \$ 20,000 and has a significant potential to increase when additional required specific subject competencies in the labor market are presented.

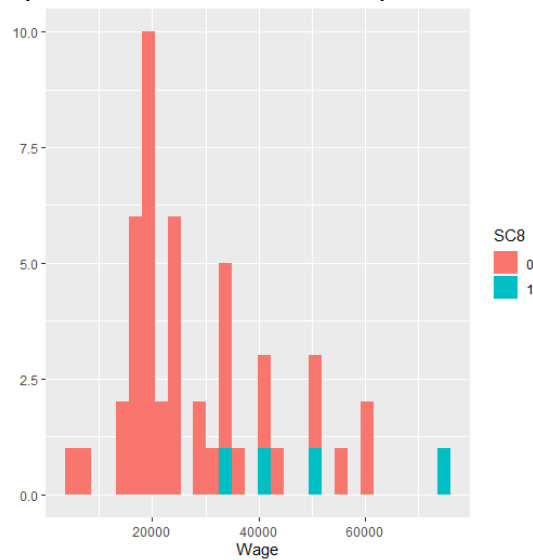


Fig. 13. Wage distribution for BA position

A system of certificates can be an effective tool to overcome a gap between educational programs [20-23] and employers' requirements [24-25]. This system should be developed jointly by university representatives and companies and will certify the students' competence in certain highly specialized fields of knowledge and confirm the quality of the education obtained through professional qualifications (fig. 14).

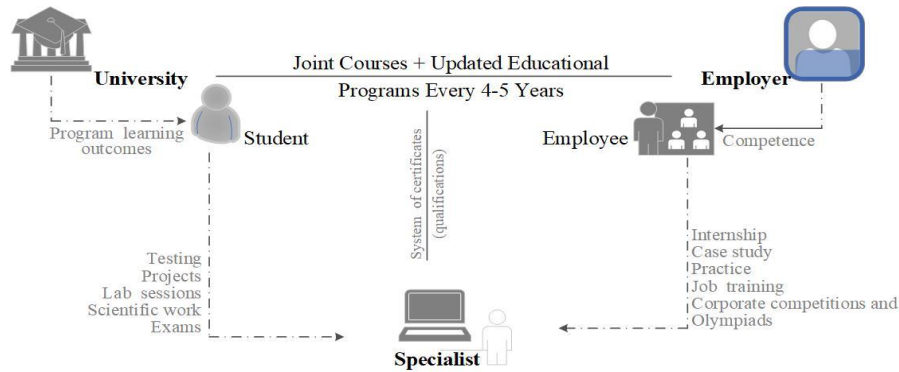


Fig. 14. Scientific-educational-practical complex of students teaching at IT majors

4. Conclusions

To cope with the gap in the quality of higher education and the real labor market requirements, the system of higher education should be reformed. Moreover, all stakeholders should involve this process, which can be guided by the successful practice of European countries and focusing on the development of soft skills. However, it is important to note that soft skills, despite their general nature, depending on the major, should be adapted for IT professionals.

For the IT industry, the most important competencies were revealed as follow: Management Accounting, Corporate Finance and Financial Statements determined an average monthly wage increase of +\$23376; the ability to form new competitive ideas and implement them in projects (start-ups) for graduates does not meet the requirements of the IT industry (JIRA Confluence, MS Project), and therefore leads to a decrease in salary by \$9062, which confirms the lack of competence in the HEA.

For other positions not covered by IT consulting, Banks Government Institutions, the most required competencies were revealed: the ability to manage and use state-of-the-art information and communication systems and technologies (including Internet-based ones, MS Access, MS Excel, MS Power Point) adds +\$29996 each month; the ability to form new competitive ideas and implement them in projects (startups), JIRA Confluence, MS Project prove that this competence is formed for other industries and raises wages by an average of \$36683.

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The data association algorithm for the formation of optional IT-courses list system

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Abstract. The article contains a study of the principles of student's educational trajectory formation by using modern technologies in data analysis. There is a mandatory requirement to have the selective component (optional to a student) among the curriculum educational components. This rule is legislated in the laws «On Education» and «On Higher Education» of Ukraine as well as in the normative documents on accreditation of educational programs, defined by the Standards and recommendations on quality assurance in the European Space of Higher Education (ESG) and the National Agency for Quality Assurance of Higher Education. However, adherence to the principles of the individual educational trajectory formation is mostly formal and is reduced to offering students a non-coherent list of courses. On the one hand, this leads to the disorientation of a student, who cannot see the systemic perspective of his future profession in the initial list of study courses, and therefore cannot consciously choose the optimal set of optional courses. On the other hand, the unknown choice of courses by students leads to situational management of the educational process at the HEI. A large number of courses create significant difficulties in managing the selection process. To analyse the process of individual educational trajectory formation, the authors propose to use methods of data association and, in particular, the apriori algorithm for the formation of associative rules. The procedure of popular sets of elective courses formation, the configuration of associative rules of educational courses choice is studied. The characteristics of these rules quality are calculated. The example of the procedure implementation in analytical platform Deductor Studio is considered.

Keywords: individual educational trajectory, selective study courses, Data Science, data association, associative rules, apriori algorithm.

1. Introduction

The prior goal of modern higher education is to prepare in HEIs competent specialists with a harmonious combination of personal and professional qualities, that are capable of self-development and self-realization in the future professional activity. In this regard, the orientation of the educational process towards the student becomes particularly relevant and valuable. It includes taking into account the individual opportunities and needs of the students. This orientation allows students to choose components of educational programs and to form an individual educational trajectory.

The educational trajectory determines the direction of the student in the educational space. Its existence is not a norm, but a fact of reality. Different scenarios for defining this trajectory are possible under different educational conditions. According to the traditional approach, the HEI defines a single trajectory of educational achievement results by students in accordance with the National standard. The more modern method offers several possible paths for groups of students with different capabilities. Both such approaches do not take into account the views of the student. Because of the goals, content, forms, methods, results are determined directly by the teacher. At the same time, a large proportion of students have a low level of motivation to achieve goals, as they do not see personal meaning in such educational activities. One way to overcome this problem in higher education is to form an individual educational trajectory.

Recognition of students' right to an individual educational trajectory is one of the progressive innovations of the «Law on Education». This law provides for «a personal way of realizing the student's potential, is formed taking into account his abilities, interests, needs, motivation, opportunities and experience, is based on the student's choice of types, forms and pace of education, courses of educational activities and their offered educational programs, educational courses and the level of their complexity, methods and means of education» [1].

The main tool for the realization of personal potential is in optional courses choice. According to the Law of Ukraine "On Higher Education" [2], students have the right to choose courses in the amount of at least 25% ECTS credits from the total educational program (paragraph 15, part 1, Article 62).

Requirements for individual educational trajectory are contained in the regulatory documents for the accreditation of educational programs defined by the Standards and Recommendations for Quality Assurance in the European Higher Education Space (ESG) [3] and the National Agency for Quality Assurance of Higher Education [4].

The authors of the article are experts of the National Agency for Quality Assurance of Higher Education and may argue that compliance with the principles of formation of individual educational trajectory in Ukrainian HEIs is mainly formal and is reduced to offering students to choose an unrelated list of courses. This leads to the disorientation of the students, who at the initial courses of study cannot see the systemic perspective of their future profession, and therefore cannot consciously choose the optimal set of optional courses. The unknown choice of courses by students leads to situational management of the educational process at the higher educational establishment. A large number of courses create significant difficulties in managing the selection

process. System analysis of the process of the individual educational trajectory formation can be effectively carried out with the help of Data Science tools [5].

2. Research Methodology

The theoretical and methodological justification for research is the fundamental principles of the system approach, analysis and synthesis of information, dialectical method in the justification of the use of information technologies.

In particular, the following scientific methods are used in research:

- association method – for combine courses into logical modules and create causal relationships between modules of optional courses;
- apriori algorithm – for the formation of frequent itemset sets of optional courses and a system of associative rules construction based on these sets;
- a graphic method – for creation of the formation scheme of frequent itemsets subsets of optional courses with various weights;
- a method of the quantitative analysis – for calculation of characteristics of support and confidence of associative rules and its sorting.

The information basis for the research is data on the content of the optional components of curricula set and results of course selection by students of the Faculty of Information Technologies of Kyiv National University of Trade and Economics.

3. Literature and Hypothesis Development

According to the National Strategy for the Development of Education in Ukraine for 2012-2021, the main direction of the educational space development is the introduction of the individualized learning concept [6]. Implementation of individualized learning is ensured by the determination of individual educational trajectory.

Basic concepts of individual educational trajectory are given, for example, in the work of I. Krasnoshchok [7]. Analysis of the advantages of its use in the educational process and review of the principles to construct an online information system supporting the student's educational trajectory is the subject of research by S. Sharov and T. Sharova in the article [8].

Various aspects of the information and communication technologies introduction in the educational process are constantly attracting the attention of many researchers.

Systematic studies of informatization of education and practical implementation of information and communication technologies in the educational sphere of Ukraine were conducted by Yu. Bykov, O. Burov, A. Gurzhii, M. Zhaldak and others in [9]. The needs of digital transformation, which require special flexibility from modern universities, the creation of a digital learning environment to support educational activities are discussed in the studies of O. Kuzminska, M. Mazorchuk, N. Morze, O. Kobylin [10]. The formation of competences in the field of information technologies was presented in the study by N. Morze and M. Umryk [11]. The development of innovative entrepreneurial universities in Ukraine on the platform of digitalization is assessed in [22]. The principles and structure of the information support system for

the individual educational trajectories as an open modular portal were investigated by A. Bogdanov, I. Chepovoy, P. Ukhan, L. Yurchuk in [12]. It analyzes Tools for Mobility, Tools for Quality, Tools for Transparency, and Portals and Databases, which can be useful for building and implementing an individual educational trajectory. The formation of an integrated quantitative assessment of the HEI activity is proposed by V. Bykov, A. Biloshchytskyi, O. Kuchanskyi, Yu. Andrashko, O. Dikhtiarenko and S. Budnik in [13].

The problems of big data processing are extremely pressing today. Scientists D. Dietrich, B. Heller, B. Yang tell how it is effective to use Data Science tools in almost all areas of human activity [14]. An associative analysis is one of the main components of Knowledge Discovery in Databases and its main component, Data Mining [15]. Practical implementation of associative rules in various fields of scientific research is represented by C. Zhang and S. Zhang in [16] and G. Bhavani and S. Sivakumari in [17].

The main purpose of the vast majority of management systems is the integrated management of HEI. Among the well-known foreign systems of automation it is necessary to assign such as MyEdu – University Automation Software [18], Eiffel Corp Services and Custom eLearning [19], CyberVision University Management System [20].

In Ukraine, at the state level, there is no more than a single state electronic database on education, which is an integrated information and telecommunications management system. The Ukrainian software market offers its solutions for the automation of the educational process. The most famous is the Automated control system of the higher educational institution ACS "University", developed by the Research Institute of Applied Information Technologies of the Cybernetics Center of the National Academy of Sciences of Ukraine [21], Computer Systems Packages "Dean's Office", "COLLOQUIUM", "PS-Staff" of the private enterprise "Politek-soft" [22], Program Complex "ALMA-MATER" of the company "Direct IT" [23] and others.

None of the control systems described above contains a module for automating the process of choosing courses. As a result of the analysis, the authors found only a few attempts of a scientific approach to solving this problem.

A. Kravets and R. Al-Shaebi in the article [24] offer a method of automated formation of the individualized curriculum. A. Kardan with co-authors describes using a neural network approach for the process of student behaviour modelling in choosing courses [25]. I. Ognjanovic, D. Gasevic and S. Dawson created a model for predicting the student course choice [26].

These approaches do not use the logical relationships between the courses that the student must choose. However, this is a necessary condition for the formation of a high-quality curriculum for the training of highly qualified specialists. The educational program must have a clear structure; educational components should be a logically interconnected system and together enable the achieving of learning goals and outcomes.

The search for associative rules is a good tool for solving the problem of establishing relationships between courses and a systematic approach to building a quality logical and structural system of educational components.

4. Objective and Context of Research

The purpose of this research is to provide a tool for students for a conscious choice of courses, to analyze the frequent itemsets of optional courses in the formation of professional qualities of future specialists. Along it is also to replace inefficient situational management with a systemic approach in the management of the educational process at the HEL.

The large volumes of modern databases have generated a steady demand for new scalable data analysis algorithms. Systematizing the complex structure of big data has led to the emergence of affinity analysis, one of the most common methods of Data Mining. The purpose of this method is to investigate the relationship between events that occur together.

One popular method of knowledge discovery is the algorithms for associative rules finding. For the first time, the associative rules finding task has been proposed to find typical shopping patterns made in supermarkets, so it is sometimes also called market basket analysis.

Associative rules are now applied to solve problems in various areas:

- identifying sets of goods in supermarkets that are often bought together or never are bought together;
- identification of a part of clients who are positive about innovations in their services;
- determining the profile of visitors to the web resource.
- identification of a part of cases where new drugs cause dangerous side effects, etc.

The authors of the article aimed to embody the idea of affinity analysis and associative rules to optimize the educational process in the formation of the individual educational trajectory of the student.

5. Results

5.1. Structure of Initial Data to Form Associative Rules

Although the National Agency for Quality Assurance of Higher Education promotes a wide selection of courses for students and claims not to limit their choice to separate blocks, the division of optional courses into logical units is a prerequisite for analyzing the structural and logical relationship between courses.

As initial data, we take the recommended optional courses of the professional training at the Faculty of Information Technologies at the Kyiv National University of Trade and Economic (Table 1). Once again, it should be stressed that there is no division of optional courses into blocks in the curricula of the Faculty of Information Technology. Courses are combined into logical units only as part of this study.

Table 1: Division selective courses into logical units

Programming Unit

Enterprise programming Java	Web-design and web-programming	Cross-platform programming	Functional and logical programming
Database and Knowledge Unit			
The technology of design and administration of databases and data storage	Technology for distributed databases and knowledge creating	Knowledge representation and processing technologies in intelligent systems	Distributed systems and parallel computing technologies
Data Processing Unit			
Data analysis technologies	Tools of business intelligence	Business analytics of an enterprise	Computer technologies of data processing
Intellectual Analysis Unit			
Expert systems	Intelligent systems	Machine learning	Artificial Intelligence
Internet Technologies Unit			
Cloud and GRID technologies	Internet technologies in business	Digital technologies in business	Digital systems and technologies
Information Security Unit			
Cryptographic methods of information security	Biometric authentication technologies in information systems	Methods and means of protecting information in computer networks	Security of Internet resources

Source: formed by the authors based on the real study curricula

5.2. Formation and intellectual analysis of relationships between units of courses

According to the Regulation on the Organization of the educational process of students, the applicants choose educational courses for the next academic year in February. During the study, students are asked to choose one course from each logic unit. It should be noted that before the survey, students had the opportunity to familiarize themselves with presentations of optional courses to raise the consciousness of their choice.

A total of 100 faculty students enrolled in the second, third or fourth study years were interviewed. Such a sample is appropriate, as it takes into account not only the desire of students of junior courses to gain knowledge in certain areas of information technology in the future but also a certain experience of students of senior courses who have already studied some of the offered courses. Results of the courses selection among students of one of the groups of the Faculty of Information Technology are presented in Table 2. In this table, the ID is the serial number of the student who participated in the survey. Each row contains the results of the student-specific selection of six of the 24 courses offered in Table 1.

First, we find single-element course sets by presenting the transaction database from Table 2 in normalized form (Table 3). In this Table U_{ij} – the course name with the course sequence number j belongs to the logical unit number i . At the intersection of the transaction row and the course, the column is 1 if the course is present in the transaction and 0 otherwise. The column amount will be the frequency at which each course appears in the selection results.

Table 2: Results of students' choice of courses from six logical units

ID	Unit 1	Unit 2	Unit 3	Unit 4	Unit 5	Unit 6
S1	Enterprise programming Java	Technology for distributed databases and knowledge creating	Data analysis technologies	Expert systems	Internet technologies in business	Security of Internet resources
S2	Cross-platform programming	Distributed systems and parallel computing technologies	Business analytics of an enterprise	Expert systems	Digital systems and technologies	Biometric authentication technologies in information systems
S3	Cross-platform programming	Distributed systems and parallel computing technologies	Data analysis technologies	Machine learning	Cloud and GRID technologies	Biometric authentication technologies in information systems
S4	Enterprise programming Java	Distributed systems and parallel computing technologies	Business analytics of an enterprise	Artificial Intelligence	Internet technologies in business	Security of Internet resources
S5	Enterprise programming Java	Technology for distributed databases and knowledge creating	Data analysis technologies	Machine learning	Cloud and GRID technologies	Security of Internet resources
S6	Web-design and web-programming	Technology for distributed databases and knowledge creating	Data analysis technologies	Expert systems	Internet technologies in business	Cryptographic methods of information security
S7	Cross-platform programming	Technology for distributed databases and knowledge creating	Data analysis technologies	Intelligent systems	Digital technologies in business	Biometric authentication technologies in information systems
S8	Enterprise programming Java	The technology of design and administration of databases and data storage	Computer technologies of data processing	Expert systems	Digital technologies in business	Biometric authentication technologies in information systems
S9	Web-design and web-programming	Technology for distributed databases and knowledge creating	Computer technologies of data processing	Expert systems	Cloud and GRID technologies	Biometric authentication technologies in information systems
S10	Enterprise programming Java	Technology for distributed databases and knowledge creating	Data analysis technologies	Artificial Intelligence	Internet technologies in business	Methods and means of protecting information in computer networks

S11	Enterprise programming Java	Knowledge representation and processing technologies in intelligent systems	Data analysis technologies	Intelligent systems	Digital systems and technologies	Methods and means of protecting information in computer networks
S12	Cross-platform programming	Distributed systems and parallel computing technologies	Business analytics of an enterprise	Expert systems	Digital systems and technologies	Cryptographic methods of information security
S13	Functional and logical programming	Knowledge representation and processing technologies in intelligent systems	Business analytics of an enterprise	Machine learning	Digital technologies in business	Methods and means of protecting information in computer networks
S14	Web-design and web-programming	The technology of design and administration of databases and data storage	Data analysis technologies	Machine learning	Cloud and GRID technologies	Cryptographic methods of information security
S15	Enterprise programming Java	The technology of design and administration of databases and data storage	Business analytics of an enterprise	Machine learning	Internet technologies in business	Methods and means of protecting information in computer networks
S16	Web-design and web-programming	Distributed systems and parallel computing technologies	Business analytics of an enterprise	Expert systems	Internet technologies in business	Methods and means of protecting information in computer networks
S17	Cross-platform programming	Distributed systems and parallel computing technologies	Computer technologies of data processing	Machine learning	Digital systems and technologies	Methods and means of protecting information in computer networks
S18	Web-design and web-programming	Distributed systems and parallel computing technologies	Business analytics of an enterprise	Expert systems	Cloud and GRID technologies	Methods and means of protecting information in computer networks
S19	Cross-platform programming	Distributed systems and parallel computing technologies	Business analytics of an enterprise	Expert systems	Digital systems and technologies	Security of Internet resources
S20	Web-design and web-programming	Distributed systems and parallel computing technologies	Business analytics of an enterprise	Machine learning	Digital technologies in business	Methods and means of protecting information in computer networks

Source: formed by the authors

Table 3: Formation of a set of single-element frequent itemsets

	Unit 1				Unit 2				Unit 3				Unit 4				Unit 5				Unit 6			
	U11	U12	U13	U14	U21	U22	U23	U24	U31	U32	U33	U34	U41	U42	U43	U44	U51	U52	U53	U54	U61	U62	U63	U64
S1	1					1			1				1					1						1
S2			1				1			1			1						1		1			
S3			1				1	1						1			1				1			
S4	1						1			1					1			1						1
S5	1					1			1					1			1							1
S6		1				1			1				1					1			1			
S7			1			1			1				1					1			1			
S8	1				1							1	1					1			1			
S9		1				1						1	1				1				1			
S10	1					1			1						1			1					1	
S11	1						1		1					1						1			1	
S12			1				1			1			1							1	1			
S13				1			1			1				1				1					1	
S14		1			1				1					1			1				1			
S15	1				1					1				1				1					1	
S16		1					1			1			1					1					1	
S17			1				1					1		1					1			1		
S18		1					1			1			1				1					1		
S19			1				1			1			1						1				1	
S20		1					1			1				1				1				1		
Sum	7	6	6	1	3	6	2	9	8	0	9	3	9	2	7	2	5	6	4	5	3	5	8	4

Source: formed by the authors

In the practical implementation of associative rule search systems different methods are used, which allow reducing search space to dimensions, providing acceptable computational and time costs, for example, Apriori algorithm [14-17]. The Apriori algorithm is based on the concept of frequent itemsets, i.e. sets with high frequency in a given number of transactions.

In the classic Apriori algorithm, a popular subject set is a subject set with support, equal to or greater than a given threshold. This threshold is called minimum support. However, the problem of establishing relationships between modules imposes limitations on the selection of single-element sets, which must contain courses from different logical units. Therefore, we form the set F_1 of single-element subsets from the most frequent itemsets of each logical unit.

Next, we find two-element sets, forming all possible combinations from F_1 two courses (Table 4). In the future, the most popular representative logical unit U_i will indicate the name of this unit.

Table 4: Formation of a set of two-elementt frequent itemsets

	U1&U2	U1&U3	U1&U4	U1&U5	U1&U6	U2&U3	U2&U4	U2&U5	U2&U6	U3&U4	U3&U5	U3&U6	U4&U5	U4&U6	U5&U6
S1			1	1									1		
S2						1	1			1					
S3															
S4	1	1		1		1		1			1				
S5															
S6													1		
S7															
S8			1												
S9															
S10				1	1										1
S11					1										
S12						1	1			1					
S13												1			
S14															
S15		1		1	1						1	1			1
S16						1	1	1	1	1	1	1	1	1	1
S17									1						
S18						1	1		1	1		1		1	
S19						1	1			1					
S20									1			1			
Sum	1	2	2	4	3	7	5	2	4	5	3	5	3	2	3

Source: formed by the authors

In Table 4 $U_i \& U_j$ defines a two-element set of two courses U_i and U_j that simultaneously chose (1) or did not chose (0) a certain student. Since in many two-element frequent itemsets F_2 we have representatives of all logical units, we can set the threshold of minimum support, which in conditions of this task we will accept, for example, equal to 3. Thus, a set of two courses will be considered popular if at least three students have chosen it.

Using frequent itemsets from F_2 , we generate a set F_3 of three-element itemsets (Table 5). To do this, we need to associate a set F_2 with itself by selecting binding itemsets. Note, k-itemsets are binders if they have common $k-1$ items. For example:

$$\{U_2 \& U_5\} + \{U_3 \& U_5\} = \{U_2 \& U_3 \& U_5\}$$

To reduce the search for associative rules, the Apriori algorithm uses the anti-monotony property: if Z is not a popular set, then adding some new subject A to the Z set does not make it more popular, meaning the set $Z \cup A$ will not be popular either. For example, the $U_2 \& U_3 \& U_5$ set will not be popular because the set $U_2 \& U_5$ is not popular.

Table 5: Formation of a set of three- and four-element frequent itemsets

	U1&U5&U6	U2&U3&U4	U2&U3&U6	U3&U4&U5	U3&U4&U6	U3&U5&U6	U2&U3&U4&U6
S1			1	1			0
S2						1	0
S3							0
S4	1	1		1		1	0
S5							0
S6							0
S7							0
S8			1				0
S9							0
S10				1	1		0
S11					1		0
S12						1	0
S13							0
S14							0
S15		1		1	1		0
S16						1	1
S17							0
S18						1	1
S19						1	0
S20						1	0
Sum	2	5	3	1	2	2	2

Source: formed by the authors

For a given set F_3 , we form the set of possible four-element sets. According to the rule of formation of many popular sets, we have only one option – the set $U_2 \& U_3 \& U_4 \& U_6$.

This set is not frequent itemset according to the anti-monotony property (itemset $U_4 \& U_6$ is not frequent). The same is shown in the last column of Table 5, which is less than the minimum support threshold. So, the set $F_4 = \emptyset$.

A graphical model of the formation of sets F_1, F_2, F_3 is presented in Fig. 1

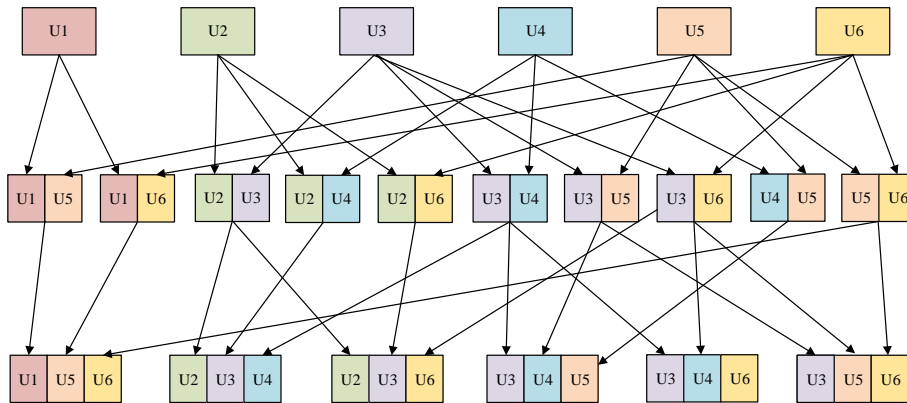


Fig.1. Graphical model of formation of sets of frequent itemset for different power. Source: formed by the authors

The next step in the Apriori algorithm is to generate associative rules. Each set of frequent itemset F_i requires a two-step procedure:

1. All possible subsets of the set F_i are generated. We denote \bar{F}_i the set of all subsets F_i .
2. If a subset f is a non-empty subset of \bar{F}_i , then the association.
 $R: f \rightarrow (\bar{F}_i \setminus f)$, where \bar{F}_i is the same subset without f , is considered.

This procedure repeated for each subset f of \bar{F}_i .

The associative rule consists of two sets of objects called a condition (antecedent, left-hand side – LHS) and consequence (consequent, right-hand side – RHS), which are signed as $X \rightarrow Y$: «If *antecedent* then *consequent*». Association rules describe the relationship between item sets, which is characterized by two main indicators – support S (support) and C (confidence).

Associative rule support $S(A \rightarrow B)$ is the part of transactions that contain both antecedent and consequent. For example, for association $A \rightarrow B$ support $S(A \rightarrow B)$ means the fraction of the number of transactions containing antecedent A and consequent B to the total number of transactions.

Associative rule confidence $C(A \rightarrow B)$ is a measure of the accuracy of a rule $A \rightarrow B$ and is defined as the fraction of the number of transactions that simultaneously contain antecedent A and consequent B to the number of transactions that contain only antecedent A.

We form a set of associative rules for the set F_3 .

For set $\{U_2 \& U_3 \& U_4\}$ $\bar{F}_3 = \{U_2, U_3, U_4, U_2 \& U_3, U_2 \& U_4, U_3 \& U_4\}$.

For set $\{U_2 \& U_3 \& U_6\}$ $\bar{F}_3 = \{U_2, U_3, U_6, U_2 \& U_3, U_2 \& U_6, U_3 \& U_6\}$.

Because support and confidence give different evaluations of the quality of an associative rule, it is often the product $S \cdot C$ of these two quantitative characteristics that are used to rank associative rules by priority (Table 8).

Table 8: Ranking of associative rules in terms of support and confidence

Rule	S	C	$S \cdot C$	Rule	S	C	$S \cdot C$
U2→U3	35.0%	77.8%	0.2722	U2&U6→U3	15.0%	75.0%	0.1125
U3→U2	35.0%	77.8%	0.2722	U1→U6	15.0%	71.4%	0.1071
U2&U4→U3	25.0%	100.0%	0.2500	U6→U2	20.0%	50.0%	0.1000
U3&U4→U2	25.0%	100.0%	0.2500	U6→U1	15.0%	62.5%	0.0938
U2&U3→U4	25.0%	71.4%	0.1786	U3&U6→U2	15.0%	60.0%	0.0900
U5→U1	20.0%	83.3%	0.1667	U2→U6	20.0%	44.4%	0.0889
U6→U3	25.0%	62.5%	0.1563	U5→U3	15.0%	50.0%	0.0750
U1→U5	20.0%	71.4%	0.1429	U5→U4	15.0%	50.0%	0.0750
U2→U4	25.0%	55.6%	0.1389	U5→U6	15.0%	50.0%	0.0750
U4→U2	25.0%	55.6%	0.1389	U2&U3→U6	15.0%	42.9%	0.0643
U3→U4	25.0%	55.6%	0.1389	U6→U5	15.0%	37.5%	0.0563
U4→U3	25.0%	55.6%	0.1389	U3→U5	15.0%	33.3%	0.0500
U3→U6	25.0%	55.6%	0.1389	U4→U5	15.0%	33.3%	0.0500

Source: formed by the authors

Thus, the Apriori algorithm has found associative rules that show which sample courses from the initial set of transactions are most often selected by students together. Such indicators will allow to build logical links between different units of courses and to develop a better strategy for managing the educational process of the HEI.

5.3. Generate Associative Rules in the Deductor Studio Analytics Platform

When we formed the set F_1 of single-element frequent itemsets, we change the traditional scheme of the Apriori algorithm and set the task of identifying links between logical units. This approach is primarily related to the complexity of analyzing associative rules for all courses. In the case of a large number of transactions and a large

number of courses, it is appropriate to use associative rule generation and processing software.

Such popular systems as Microsoft Power BI [27], R [28], RapidMiner [29], Deductor [30] and others have Associative rule tools. Next, we briefly describe the process of processing associative rules in the analytical platform Deductor Studio [31].

Deductor Studio uses a special unit «Associative rules» that implements the Apriori algorithm to solve such problems. When configuring the unit, it is possible to set minimum and maximum values of support and confidence of associative rules, calculate additional characteristics of the importance of rules (lift, leverage, improvement), create various visualizers (diagram, rule tree, OLAP cube).

The results of the survey of 100 students are processed. The Deductor system allowed the formation of 1,123 frequent itemsets with a capacity of up to five courses (Fig. 2) and found 8,594 associative rules (Fig. 3).

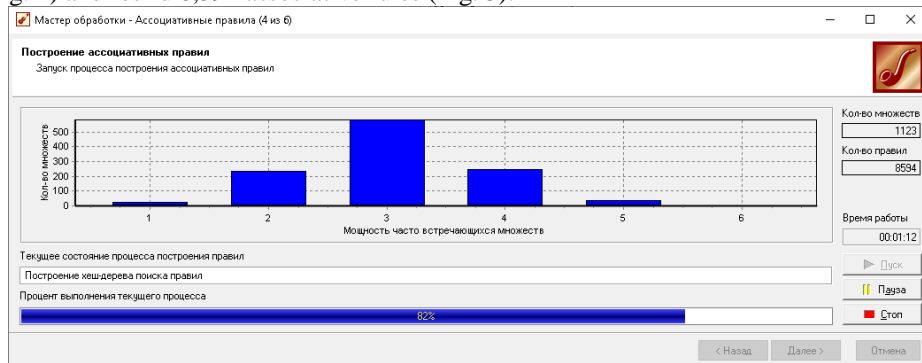


Fig.2. Formation of frequent itemsets in Deductor Studio. Source: formed by the authors

№	Номер правила	Условие	Следствие	Поддержка		Достоверность	Лифт
				Кол-во	%		
2640	2640	Cryptographic methods of information security Web-design and web-programming	Distributed systems and parallel computing technologies	2	2.00	50.00	2.000
2641	2641	Distributed systems and parallel computing technologies Web-design and web-programming	Cryptographic methods of information security	2	2.00	25.00	1.000
2642	2642	Cryptographic methods of information security	Distributed systems and parallel computing technologies Web-design and web-programming	2	2.00	8.00	1.000
2643	2643	Distributed systems and parallel computing technologies	Cryptographic methods of information security Web-design and web-programming	2	2.00	8.00	2.000
2644	2644	Web-design and web-programming	Cryptographic methods of information security Distributed systems and parallel computing technologies	2	2.00	8.00	1.000
2645	2645	Cryptographic methods of information security Enterprise programming Java	Internet technologies in business	2	2.00	50.00	2.381
2646	2646	Cryptographic methods of information security Internet technologies in business	Enterprise programming Java	2	2.00	33.33	1.754
2647	2647	Enterprise programming Java Internet technologies in business	Cryptographic methods of information security	2	2.00	28.57	1.143
2648	2648	Cryptographic methods of information security	Enterprise programming Java Internet technologies in business	2	2.00	8.00	1.143
2649	2649	Enterprise programming Java	Cryptographic methods of information security Internet technologies in business	2	2.00	10.53	1.754
2650	2650	Internet technologies in business	Cryptographic methods of information security Enterprise programming Java	2	2.00	9.52	2.381

Fig.3. The result of the formation of associative rules in Deductor Studio. Source: formed by the authors

6. Conclusion

The formation of an individual educational trajectory is one of the main conditions identified in the guidelines for quality assurance in the European Space of Higher Education (ESG). A large number of courses creates significant difficulties in managing the choice process and often leads to situational management of the educational process in the HEI. The existing automation systems implement the complex management of a higher education institution and do not contain a module for automating the process of choosing academic courses.

As a systematic approach to manage the process of an individual student curriculum forming, we propose an algorithm based on the use of associative rules.

As a result of the Apriori algorithm using, we identified the associative rules of communication between educational courses chosen by the students together. The manual mode processing of 20 transactions revealed 18 popular course sets and 26 associated associative rules. The application of the Deductor system to process 100 transactions allowed the formation of 1,123 frequent itemsets and the identification of 8,594 associative rules. The number of rules that should be used in the management of the learning process depends on the minimum support threshold set, the confidence or their production.

The use of associative rules makes it possible to build logical links between different units of courses, to form an individual educational trajectory of the student and to develop a better strategy for managing the educational process of the HEI. It helps students to enhance their background and knowledge by giving them the solid logical system of courses. This approach helps the HEI's management to be objective in the funds' allocation and staff management.

Obviously, the proposed approach requires further software development, which can be more effectively implemented using business intelligence tools such as Python, R, Microsoft Power BI.

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Educational Computer Modelling in Natural Sciences Education: Chemistry and Biology Aspects

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Abstract. The article analyzes the research that addresses the issue of using computer models in the educational process. It covers the aspects of the use of computer modelling in natural sciences subjects, namely: chemistry, biology. It analyzes the students' interest in choosing a future profession, connected with chemistry and biology. The article offers the definition and substantiation of the model of educational computer pattern and the definition of its components (graphic, mathematical, strategic, animation) and features (mono-subject, poly-subject / simulation, play-based, algorithmic / poster, laboratory, quest / variant / character-based / achievable). It substantiates the stages of designing a research task. It covers the methodical basics of computer modelling in the implementation of a STEM lesson in chemistry. It describes the methodological basics of using computer modelling to work independently at the lessons of biology. The present research also summarizes the results of the teacher survey on the usefulness and ease of use of computer modelling in the educational process. The priorities of the students in the study of subjects of the natural and mathematical cycle are determined. Computer modelling is found to be an effective tool for improving the quality of science education that requires the development of a teacher training system, cognitive tasks and organizational foundations of the educational process.

Keywords. Educational Computer Modelling, Natural Sciences, Chemistry, Biology, ICT in education, CMODS, STEM, Teacher Development, Simulation.

1 Introduction

The rapid introduction of STEM education has prompted foreign universities to create the latest resources and to reload existing educational needs of the 21st century, namely the creation of digital educational content, including digital educational computer models.

In 2017, the Institute of Information Technologies and Teaching Tools of the National Academy of Pedagogical Sciences of Ukraine conducted a survey in which 70% of teachers indicated that they did not use computer modelling in class. The main reasons for the low activity are the following: lack of access to computers, the need for access to the Internet, lack of methodological resource books for lessons.

During 2018-2019, the Stanford University CK-12 Foundation Team conducted a series of webinars on teacher training in computer models, electronic textbooks and online tests. The survey established that 75% of teachers did not use these resources in the educational process. It identified the main problems: lack of information, the need for constant access to the Internet and the lack of skills to use the latest technologies (<https://www.ck12.org/>).

Nowadays, the number of digital educational resources that a teacher should operate in his / her professional activity is as follows: digital texts, educational videos, interactive tasks, quizzes, question banks, thematic web resources, photo galleries, virtual museums, blended learning, digital laboratories, digital laboratories maps, computer modelling, etc.

As you can see, computer modelling is on this list and therefore remains an up-to-date method of scientific knowledge. The modelling method makes it possible to study objects, design logical constructions and scientific abstractions during the experiment. However, the lack of information and systematic teacher training (enhancing their IC-competences) led to a significant gap in the needs of the 21st century school and the teacher's professional growth in the use of the latest digital content and digital learning tools.

2 Analysis of latest research and publications

Students' acquisition of knowledge is more effective in the process of activity. Researchers at M.P. Dragomanov National Pedagogical University (O.V. Matviychuk, V.P. Sergienko, S.O. Podlasov) established that the development of computer models of physical phenomena could serve as such an activity. Creating a computer model, first of all, requires the student to have a deeper understanding of the mathematical description and the nature of the processes that take place. In this case, the process of building a computer model can be organized with a gradual complication and approximation to reality, in accordance with the didactic principle of "of simple to complex" [10].

However, most scientists are inclined to think that not only computer models are shaping students' perceptions of the world around them. The quality of education can be ensured by the systematic use of computer modelling in science subjects to solve educational cognitive tasks.

The interest of scientists in the use of computer modelling in the secondary education process is growing, due to a number of articles published in the last two years. Scientists have raised problems and substantiated the following directions of use of computer modelling in the educational practice: activation of students' cognitive activity in physics lessons by means of computer modelling [15]; criteria development

for selecting computer models for use in the educational process [2]; determination of ergonomic requirements for the use of computer models in general secondary education institutions [9], extensive discussion of the issue of the students' subject competencies formation by means of computer modelling [12]; theoretical aspects of simulation modelling in physics training [16], aspects of the students' safe work on the Internet, in particular in the process of computer modelling [1].

3 Methods of Research

The study was conducted within the framework of the "Computer Modelling System of Cognitive Tasks for Forming the Students' Competences in Natural Sciences and Mathematical Subjects" experiment. The methods used in the research process include the analysis of theoretical sources, generalization of the best pedagogical practices of foreign and domestic specialists regarding the use of computer modelling and its use in student learning; synthesis, generalization and conceptualization for the development of the main research provisions; design of the educational computer model, surveys of teachers; generalization of results.

4 Research Results

4.1 Educational computer model design

A significant contribution to the development of the issue was made by the scientists of the Institute of Information Technologies and Teaching Tools of the National Academy of Pedagogical Sciences of Ukraine. During 2018-2019, within the framework of the "System of computer modelling of cognitive tasks for forming competences of students in natural sciences and mathematical subjects" scientific research, they developed a conceptual system of designing the educational computer model (Fig. 1), which is the key to understanding the direction development of ICT-technologies, including computer modelling for the educational industry

By the educational computer model (ECM) we will mean software tools for animation visualization of phenomena and processes, creation of action strategies, execution of numerical calculations of any level of complexity and aimed at identifying and solving tasks of different types [7, 8].

The purpose of designing / developing a computer model: to study the properties of objects and processes.

Developer and user categories: a teacher, a student, a professional programmer.

The educational computer model encompasses the following basic components (graphic, strategic, mathematical, animated). *Graphic* – representation of objects, processes graphically (as an image). *Mathematical* – presentation of complex mathematical calculations in the process of experimentation. *Animation* – accompanying support of the experiment results with dynamic changes in the image. *Strategic* – further steps depend on the previous selection of the dataset.

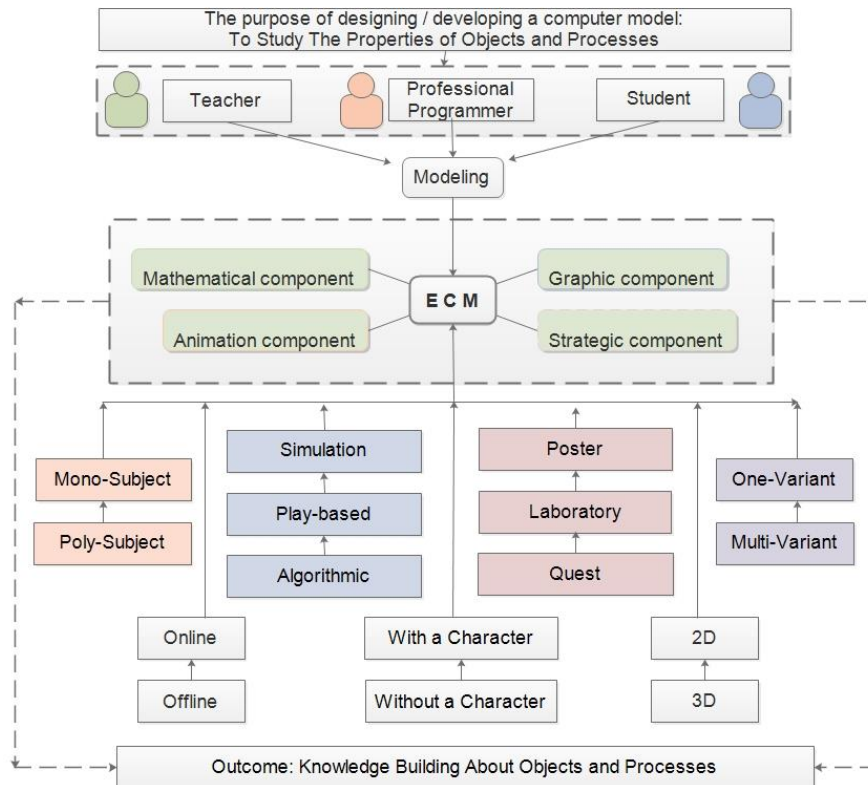


Fig.1. The system of designing the educational computer model.

Outcome: knowledge building about objects and processes.

The main classification features of the educational computer model are given in Table 1.

Table 1. Main classification features of the educational computer model.

Features	Content
Mono-Subject	Designed for one subject
Poly-Subject	One model can be applied to several subjects
Simulation	Performs a simulation of a process or phenomenon
Play-Based	Has an educational strategy, variability of choice of decisions
Algorithmic	Demonstration of the given algorithm execution
Poster	Implements one of the aspects: conformity, comparison
Laboratory	Performing a sequence of activities to get the result (creative elements included)
Quest	Considers the sequence of activities based on the previous result
Variant	Provides the problem-solving of one or more variants (one-variant / multi-variant)
Character-based	With / without a character
Achievable	Online / Offline

4.2 Application of educational computer models (ECM) in high school

Definition of the aims of ECM application:

- creation of a single educational information environment;
- formation of the student' information culture;
- formation of key and research competences of students in natural and mathematical subjects;
- formation of the individual trajectory of the student's development;
- preparation of students for independent educational and cognitive activity;
- improvement of the quality of knowledge acquisition.

Let's consider the application of educational computer models in chemistry and biology lessons

4.2.1. The use of the educational computer model at the STEM chemistry lessons

Chemical education is one of the important components of the general culture of a person living in the 21st century, who studies in the conditions of continuous creation of new chemical products and should be aware of environmental risks. The chemical knowledge gained by students in elementary school contributes to the discovery of the mysteries of the world through the knowledge of the processes of life of organisms at the molecular level, and computer modelling makes it possible to simulate these processes in the classroom.

However, the analysis of the results of the external independent testing showed that the number of graduates who choose the subject of chemistry to take EIT tests is decreasing annually: 2017 – 8%, 2018 – 6.3%, 2019 – 4% (of the total number of participants) (<http://testportal.gov.ua/reg/>).

This situation is conditioned by the fact that education needs transformation regarding the formation of educational environment and educational activity of students in the 21st century. The digital environment of students requires the formation of a digital educational environment, new perspectives on the knowledge of the surrounding world, values. Nowadays, the transformation of the educational environment has become a major systematic factor in the development of general secondary education. In order to understand the relevance of STEM education for general secondary education institutions, it is advisable to analyze the digital environment of students in everyday life: mobile phones, Internet, personal electronic cash desks, school electronic access system, electronic diary, blogs and websites, distance courses, electronic cards for travel, etc.

It is the introduction of STEM education that allows for the modernization of methodological foundations, content, volume of educational material of subjects of the natural and mathematical cycle, technological process of learning and formation of educational competences of a qualitatively new level [13]. It also contributes to the better preparation of students for further education, which requires different and more technically sophisticated skills, including the application of mathematical knowledge and scientific concepts.

The implementation of STEM education by teachers is carried out with the help of information and communication technologies that have changed the educational environment and opened new opportunities for organizing educational activities of stu-

dents in chemistry lessons. STEM education involves the orientation and fulfillment of practical tasks in the learning process using modern information and communication technologies, including computer modelling [16].

Computer modelling in chemistry lessons is used to study chemical phenomena and experiments that require sophisticated laboratory equipment or related to the use of explosive and expensive substances, to form research skills, cognitive interest, enhance motivation, and develop design thinking. The student can investigate the phenomenon by changing the conditions of the experiment and its course, comparing the results obtained, analyzing them, drawing conclusions and using them to self-test their knowledge [11].

The requirements for education of modern students are changing due to the trends of the development of education. Nowadays it is important not only to provide the student with a theoretical material, but also to form a competency for him/her to solve cognitive tasks (research, problem, applied) in the subject of chemistry. Other important aspects are the development of creativity in students, persistence in the search for solutions, team learning, the use of modern tools and devices to solve the task [6].

During a STEM lesson, students can use mobile phones and tablets, and the elements of computer modeling can be mastered in additional lessons. They may also get acquainted with the principles of computer modeling systems (CMODS) such as MANLab, STEM Alliance, Scientix, STEM Lesson Microsoft Education, Minecraft: Education Edition, PhET, computer models on the portal CK-12.org, GoLab and others.

The group work used during the STEM lesson enables students to develop the following skills: express their own opinions, defend their position, collaborate in a team, perceive the point of view of another team member. Introducing STEM lessons will teach students how to solve research problems, formulate assumptions / hypotheses, apply original ways of finding information, and develop analytical and critical thinking.

Let us consider an example of the students' group work using educational computer models during a STEM lesson.

The teacher prepares tasks for each team in the form of a QR-code.

The design of tasks is carried out according to the following procedure (Fig. 2):
The first stage – formulation / description of the life situation.

The second stage – hypothesis formulation, assumption formulation.

The third stage – search for more information to solve the problem.

The fourth stage – selection of effective ways of solving the problem (refutation or confirmation of the hypothesis).

The work in the classroom begins with the announcement of the topic of the lesson: “Chemical equations” and the formation of working groups: scientists, technologists, engineers, mathematicians.

Group of scientists: analyzes theoretical material, generates messages for the class about the discovery and application of the Law of Conservation of Mass of Substances.

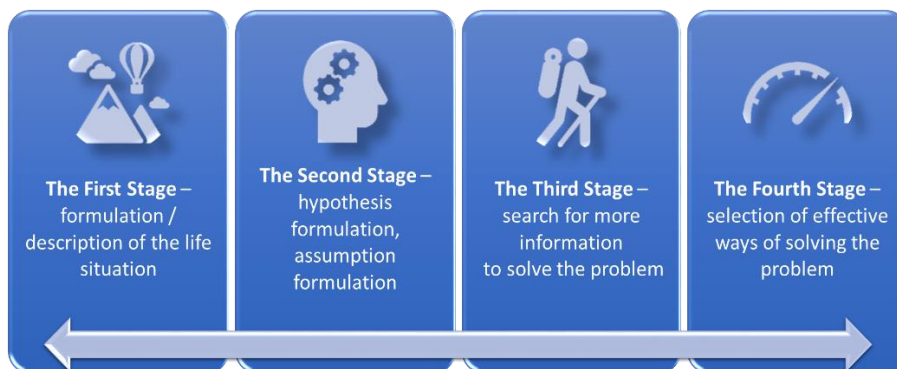


Fig. 2. Stages of the research tasks design.

Group of technologists: makes models of substances molecules involved in chemical reaction from plasticine.

Group of engineers: performs tasks on the board – balances chemical equations.

Group of mathematicians: calculates the number of atoms, molecules involved in a chemical reaction.

The teacher announces the next stage of the lesson – independent work. All students open gadgets and, with the help of an educational computer model, begin to perform the following tasks (Fig. 3-4):

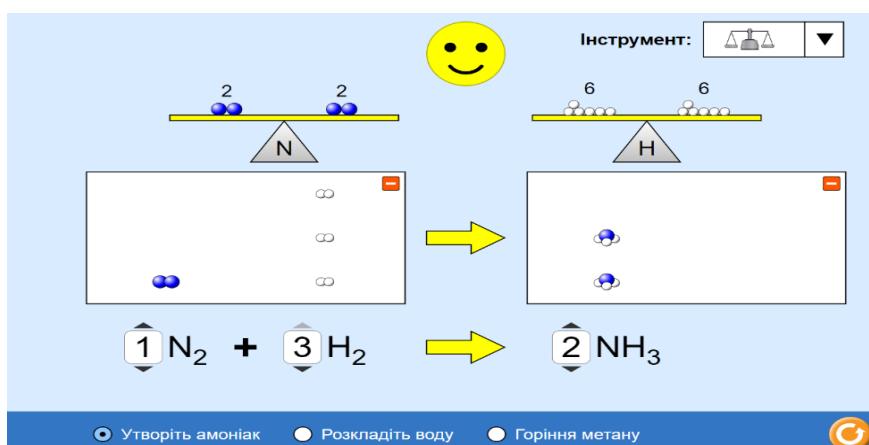


Fig. 3. Task “Balance the chemical equation” (<https://phet.colorado.edu>).

- Balance the chemical equation.
- Experimentally check if the number of atoms of each element is retained in the chemical reaction.
- Describe the difference between coefficients and indices in the chemical equation.
- Explain the transition from symbolic to molecular representation of the matter.

After mastering the basic skills, students return to their working groups to discuss the results and formulate conclusions.

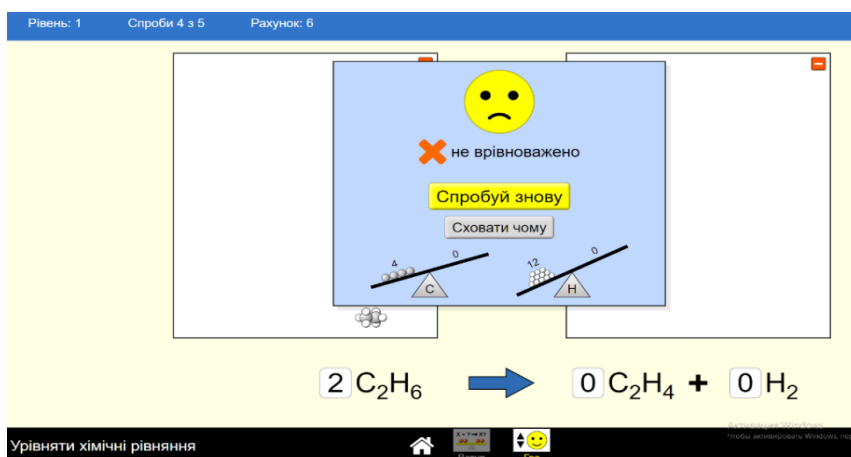


Fig. 4. The outcome of the task “Balance the chemical equation” (<https://phet.colorado.edu>)

The teacher uses the formative assessment technology to test students’ learning in the classroom. This could be a signal card, a smiley-face emoji, quick-fire questions or a demo on an interactive test board before a lesson developed in LearningApps (<https://learningapps.org/>).

4.2.2. The use of the educational computer model at the lessons of biology

The analysis of the results of external independent testing allowed us to conclude that the number of graduates who choose the subject of biology for the EIT tests is decreasing annually: 2017 – 33.9%, 2018 – 25.3%, 2019 – 24% (of the total number of participants) (<http://testportal.gov.ua/reg/>).

The students point out that the subject is interesting but difficult to understand, as it is hard to understand that you do not see. Drawings, posters, mock-up models, which are displayed on separate topics, do not give a complete picture of the content of the subject. It is possible to activate the cognitive activity of students with the help of interactive visual aids. The development of IC-technologies, in particular mobile applications, has given impetus to developers to create such educational interactive visual aids, in particular in biology subject.

Teaching students through the use of mobile applications is not common in general secondary education institutions. In addition, the gadget in the hands of the child does not serve him/her as a means of learning – there is no scientific and methodological support for the use of mobile applications in the educational process. However, the development of Internet technologies, educational mobility, and widespread access to mobile applications give impetus to the use of mobile phones in the study of particular research projects and the use of computer modeling in the study of object characteristics and natural processes at the lessons of biology.

The use of models in the process of teaching biology and ecology school subjects has always been an up-to-date method. But they mostly used to be mock-up models (made of cardboard, plastic or wood). The innovative approach lies in the use of com-

puter models and modelling of natural processes, which increases the cognitive activity of students, broaden their outlook, and promotes better assimilation of the educational material.

The developers offer the following mobile applications: human anatomy, internal human organs, biological processes, bacteria, molecular genetics and more. They also provide tests for the school course in biology and the complex preparation for the EIT in biology (Fig. 5).

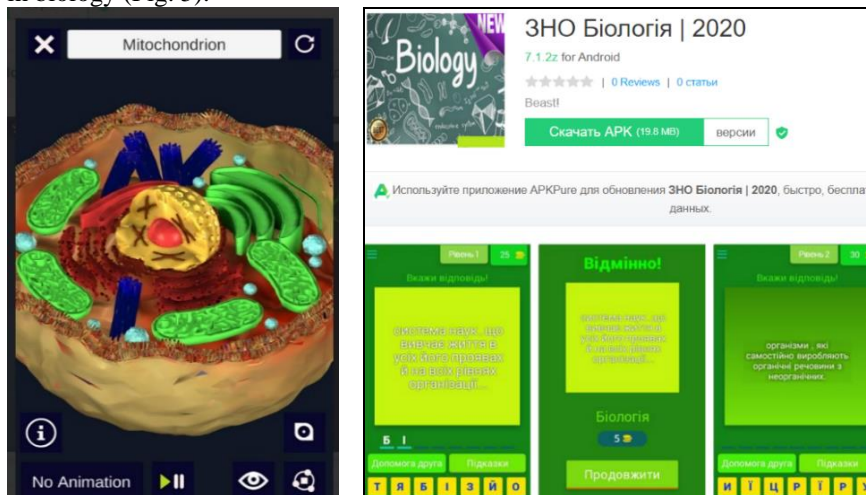


Fig. 5. Mobile applications in biology.

The applications offered by the developers can be subdivided into four groups: theoretical material, tests, dictionaries, 3D models (Fig. 6).



Fig. 6. Human body. 3D model.

There are very few computer models that can be used to perform modelling to study the characteristics of objects.

With the advent of computer models on the PhET portal, it is possible to carry out research tasks in the context of a school biology study. Toad preparation, 3D tour of the human body, immersion in different biomes – all these incredibly complex biological studies can be done with mobile applications and computer models.

The advantages of computer modelling in biology include: finding different ways to confirm / refute hypotheses; repeated experiment with different input data.

The main tasks of computer modelling while studying biology are the following: obtaining solid knowledge of the subject; study of complex issues in biology; search skills development, analysis and synthesis skills; study and application of modelling method in practice.

Experience shows the appropriateness of using PhET computer models in biology lessons in the process of mastering new material (processes illustration, their modelling, motivational training); testing knowledge; developing skills; conducting laboratory and practical classes; organization of research activities; integration of subjects; STEM training; while the most effective perception of information is provided by a combination of verbal and visual forms of its presentation [3].

When a student works with his/her own mobile phone, he/she usually does independent work. Independent work is a learning activity that is carried out by the student on his/her own for the purpose of mastering knowledge or mastering skills. Here are the signs of independent work: the presence of a specific task; performance evaluation criteria; forms of checking the performance; the obligation to do the work without assistance.

While planning the independent work using computer models in class the teacher should identify: its place in the lesson structure; the volume of work depending on both the level of students' readiness and the complexity of the research tasks; difficulties that may arise in the course of performing independent work; ways to check and evaluate students' performance.

It is desirable to discuss the results of students' independent work during the lesson: working in pairs (comparing results), mini groups (drawing conclusions), formative assessment (signal cards, quick-fire questions).

In the course of working on research assignments, it is advisable to organize group work for students, which requires the development of additional instructions.

To determine the degree of mastering the material and to clarify difficult moments in the process of mastering basic knowledge, the teacher conducts independent students' work, develops the tasks (Table 2) and formulates the problematic question: "What happens if you change your diet and use more protein and less carbs, but still maintain the same amount of calories?" and checks if the computer equipment (cell phones, tablets) is available to students.

Table 2. Card for "Food and exercise" computer model.

Cal/day	2000	2000
Proteins	600	806
Carbs	800	559
Fats	600	634
Conclusions:		

To find the correct answer, students should suggest assumptions / hypotheses to use the PhET computer model (Fig. 7) to test them.

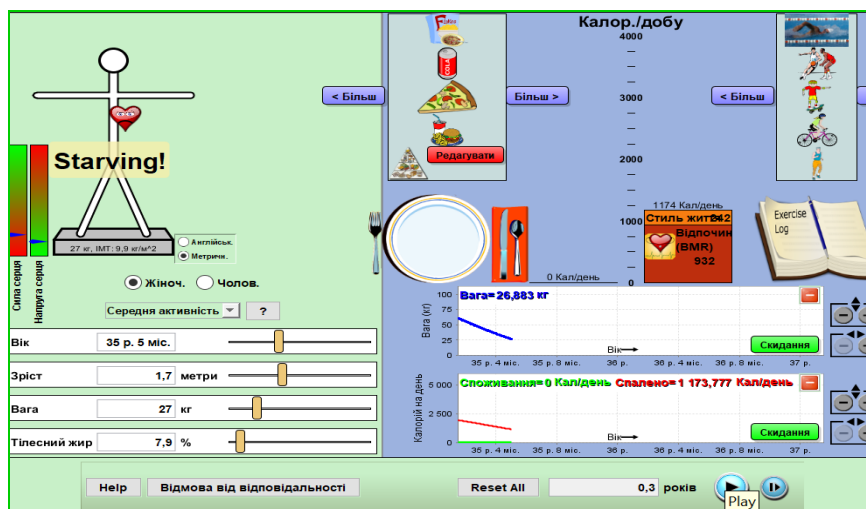


Fig. 7. “Food and exercise” computer model (<https://phet.colorado.edu>)

It is followed by the summary of the results and the formulation of the conclusions, which the students write in the table.

At the stage of formative assessment, students show the correct answer with signal cards: red card - weight will decrease; yellow card - weight will increase; green card - the heart rate will increase; blue card - the changes depend on the balance of your exercise and calorie intake, so there is not enough information.

5 Discussing of the usefulness and ease of using the educational computer modelling in teachers’ work

In order to find out the usefulness of computer models in teachers’ work, surveys were conducted in 39 Ukrainian educational institutions.

28.2% of teachers answered “no” when asked whether computer modelling would facilitate the work of a teacher while presenting new material (Fig. 8). Its use does not facilitate the work of the teacher: it takes extra time to develop tasks (2-3 options), organize student access to computers. Moreover, computer modelling is not integrated in the curriculum, there are no tasks in the textbooks, the academic time is not provided for such a kind of educational activity.

Analyzing the answers to the question of whether computer modelling is useful in the professional work of teachers, it was found that 87% of teachers, however, considered it useful (Fig. 9).

An important aspect for the development of computer modelling is the availability of the latest IC-technologies, the ease of their use as tools and their harmonious integration into the educational process. Analyzing the answers to the question of

whether computer modelling is easy to teach to students, it was found out that more than 74% of teachers consider it simple (Fig. 10).

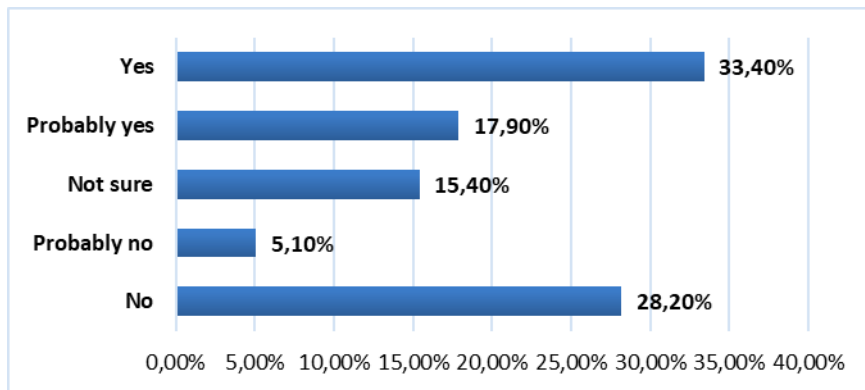


Fig. 8. Assessment of changes in the organization of the teacher's work.

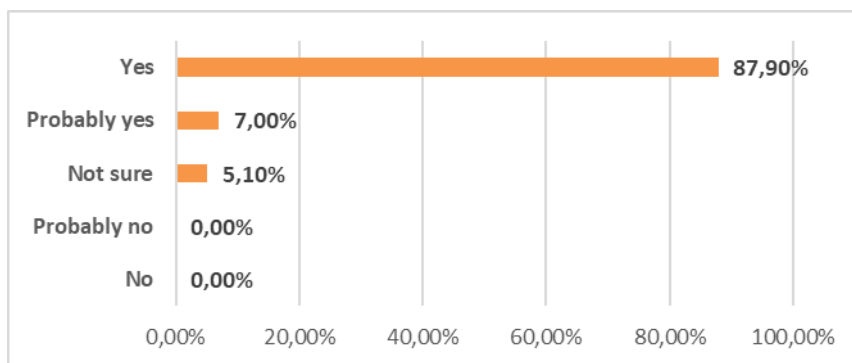


Fig. 9. Assessment of usefulness for the educational process.

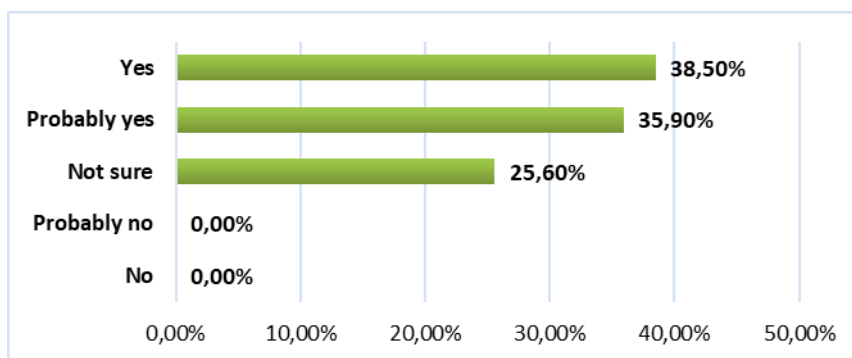


Fig. 10. Ease of use in the educational process.

The analysis of the results (Fig. 11) regarding the ease of computer modelling use in the educational process show that 25% of teachers recognized that there was a need to

work out such skills with students (lack of experience). Teachers also have fears that something may not turn on or download during the lesson.

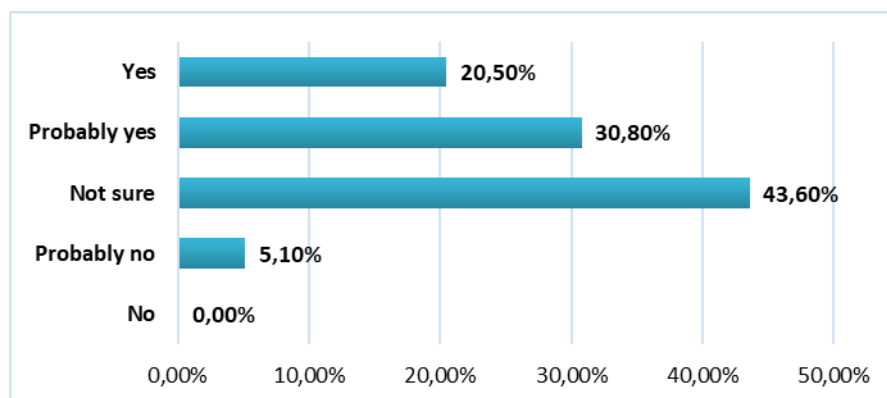


Fig. 11. Ease of the tool use.

There is a need to introduce changes both to the organization of the educational process and to the content of teaching natural and mathematical sciences for computer modelling to become an effective, easy to use tool for teachers. An important factor is the teachers' training in using the latest IC-technologies [7].

Therefore, systematic training of teachers to use computer modelling in the educational process is relevant, highly sought and timely. Such an impetus for the development of the teacher, improvement of his/her skills to work with the latest technologies will help to improve the quality of teaching, his/her digital and professional competence.

6 Conclusions and recommendations for further research

The use of computer modelling in the educational process is one of the priority areas for improving the quality of science education in general secondary education institutions. Not only will computer modelling help to better understand the content of the subject and to display environmental information, but it will also open up new opportunities for the teacher to organize the educational process, to form an individual trajectory for students' development, to organize independent and group work.

Chemistry and biology school subjects are not priorities for students in general secondary education, but they are important for the development of economy, society, and such fields as health care, ecology, agriculture.

Therefore, this contradiction must be resolved at the stage of the child's personality formation – at the school age. To this end, the content and the learning process should be improved.

The educational environment of these subjects should be filled not only with mock-up models and test tubes, but also with new equipment for students' research, including computer equipment and an Internet access point.

The use of computer modelling in STEM chemistry lessons will make it possible to use study time effectively, interestingly and productively. Under such conditions, students' theoretical knowledge will be backed up by practical skills.

The system of research assignments will enable the student to understand the processes occurring in nature, to check assumptions in practice, to draw conclusions and to discuss them with classmates [14], [17]. All these processes will activate the students' cognitive interest, accordingly, increase the quality of the educational process.

The use of computer modelling at the lessons of biology will simulate biological processes and phenomena, make virtual observations of biological objects, examine in detail their structure, the functioning of individual organs and systems, study the processes occurring in living organisms at the cellular and molecular levels [4], [5],[8].

Interactive models open cognitive opportunities for students by turning children from passive observers into active participants in virtual experiments.

Therefore, computer modelling is an effective tool for improving the quality of natural sciences education that requires the development of a teacher training system, cognitive tasks and organizational foundations of the educational process.

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The Review of the Adaptive Learning Systems for the Formation of Individual Educational Trajectory

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Abstract. The article is devoted to the review of the adaptive learning systems. We considered the modern state and relevance of usage of the adaptive learning systems to be a useful tool of the formation of individual educational trajectory for achieving the highest level of intellectual development according to the natural abilities and inclination with the help of formation of individual trajectory of education, the usage of adaptive tests for monitoring of the quality of acquired knowledge, the formation of complicated model of the knowledge assessment, building of the complicated model of the subject of education, in particular considering the social-emotional characteristics. The existing classification of the adaptive learning systems was researched. We provide the comparative analysis of relevant adaptive learning systems according to the sphere of usage, the type of adaptive learning, the functional purpose, the integration with the existing Learning Management Systems, the appliance of modern technologies of generation and discernment of natural language and courseware features, ratings are based on CWiC Framework for Digital Learning. We conducted the research of the geography of usage of the systems by the institutions of higher education. We describe the perspectives of effective usage of adaptive systems of learning for the implementation and support of new strategies of learning and teaching and improvement of results of studies.

Keywords: Adaptive Learning Systems, Individual Approach in Education, Individual Trajectory of Education.

1 Introduction

1.1 Problem statement

In the context of the modern progressive development of informational technologies, the education is experiencing global changes in the direction of rise and improvement

of the quality of educational services and as the result the increase of intellectual potential of the society. Therefore, the modern education should be aimed at the interdisciplinary and transdisciplinary as the result of implementation of the competent and student-centered approaches, that is realized by the implementation of individual educational trajectories in the educational process. In view of the labor intensity of the process of building of individual educational trajectory that is aimed at the achievement of the highest level of intellectual development according to the natural abilities and inclinations of each subject, the reevaluation of ideas of adaptive learning on the systems of machine learning appears to be appropriate. The expansion and diversification of educational services at the expense of usage of intelligence and adaptive systems of learning is achieved with the help of the development of adaptive tests for monitoring of the quality of acquired knowledge, the formation of complicated model of the knowledge assessment, building of the complicated model of the subject of education, in particular taking into account social-emotional characteristics. The result of the effectiveness of usage of the adaptive learning systems in the educational process is the reduction of the amount of students, who decided to stop studies.

1.2 Problem state of the art

The usage of adaptive opportunities of the modern technologies in education is reviewed by great amount of researches and is presented at the large-scale profile scientific conferences. The issues of application of the intelligence systems in education are considered in following range of the researches [1; 2; 3]. The principles of adaptive learning are considered in number of studies: [4; 5]. To the issue of application of the systems on the base of the adaptive hypermedia in educational process are devoted such works as [6; 7; 8]. The thorough study of the systems of adaptive testing is conducted in the framework of research [9], and the issue of application of the computer neural network technologies as the tool of individualization of education was researched in works [10; 11; 12]. The designing of intelligence system for the analysis of educational qualifications frameworks is considered in [13; 14]. Realities and prospects of distance learning in different aspects is considered in [15; 16; 17; 18; 19; 20]. However, the problem of application of the adaptive learning systems at the domestic institutions of higher education did not find sufficient display.

The aim of article is the analysis of functional opportunities of adaptive systems for the formation of individual trajectory of education.

2 The results of research

2.1 The main information regarding the technologies of adaptive learning

In the framework of the conducted educational reform takes place the quality transition of the system of modern education to mainly competence approach in education, built on the paradigm, which provides for the formation of individual educational trajectory for every student. In particular, during the round table on the topic “The educational politics in the terms of the informational society”, held on the 24th of May, 2016 by the

Committee on Science and Education and the Committee on Information and Communication together with the Association of Information Technology Enterprises of Ukraine, particular attention was emphasized on the fact that the information and communication technologies allow to carry out the individual approach and development of every personality according to the individual styles of studies, using their individual trajectories of education – thus, the talents of every personality can be developed, and not only teach everyone in the same way. Also, the Law “On Education” [21], the addition to which was expanded by such notions as “individual educational trajectory”, “individual program of development” and “individual curriculum”, has acquired changes in the direction of the assistance of formation of individualized education. The adaptive learning is the technological pedagogical system of forms and methods, that facilitates the effective individual education, and the combination of this technology with the opportunities of modern information communication technologies has the considerable potential for education. The important role in the implementation of new educational paradigm plays the technology of AL, which relies on the achievement of modern information communication technologies.

The application of the adaptive learning systems has the range of advantages, namely the opportunity of observance of individual convenient tempo of education and mastering of the specific material, that can significantly accelerate the process of acquirement of new information; the objectivity of the results of education and assessment of final result; the only system of assessment that gives the possibility to make the process of studies impartial; the complex of tasks can be created taking into account the separate way of perception of information by every student [22, p. 111]. Also to the advantages of the application of adaptive learning systems we can include the reduction of non-productive waste of live work of a teacher, who in this case is transformed to a technologist of the modern educational process, in which the leading role is attached not only to the educational activity of pedagogue but to the training of pupils themselves; providing pupils with the wide opportunities of free choice of their trajectory of learning in the process of school education; the foresight of differentiated approach to pupils, based on the individual previous experience and the level of knowledge (their own intellectual baggage, which determines the degree of understanding by pupil of new material and his interpretation); the raise of the efficiency of control and assessment of the results of studies; the increase of motivation of learning; the assistance of development of the productive, creative functions of thinking, the growth of intellectual abilities, the formation of operational style of thinking in pupils.

The research of peculiarities of usage of the ALS, the territorial characteristics of implementation in the educational process are important due to the fact that the application of the adaptive learning systems has a lot of advantages.

2.2 The existing adaptive learning systems and their classification

For the conduction of research of the available adaptive learning systems let's consider the existing types, relying on the classification that is provided in the researches [23,

pp. 14-18]; [24]; [25, p. 130], we will describe several types of the adaptive systems of learning.

Macro-adaptive system – is the system that adapts the educational material for pupils at the macro level, grouping pupils according to the results of testing in groups. The participants have the common trajectory of education in the group, but such approach leads to the poor adaptation of education.

Micro-adaptive system – is the system that carries out the adaptation of education at the micro level, constantly revealing and analyzing the profile of pupils on the base of their activity and provides personified instructions. Such approach is more effective, as the individual trajectory of learning of every pupil is formed.

Aptitude-treatment interactions system (ATI) – is the system that is designed for big amount of people, but forms the individual instructive strategies, which are built on the base of specific propensities and characteristics of a pupil (for example, intellectual abilities and cognitive style, knowledge, style of learning, etc.). Such system allows a pupil partially or completely to adjust the process of his learning.

Intelligent tutoring system (ITS) – is the system that is realized by the means of artificial intelligence and is the hybrid combination of Micro-adaptive system and Aptitude-treatment interactions system. Such system for the formation of adaptive strategies of learning takes into account as propensity and also the needs of a pupil, applying the complicated structured model of a user.



















Adaptive Hypermedia System (AHS) – is the hypermedia system that is built with the help of artificial intelligence and uses the model of a user, in which the pupil's personal information about knowledge, interests and goals for the adaptation of content and navigation in the hypermedia space is contained. The pupils, who have different goals and knowledge, can get interested in various information that is presented on the hypermedia pages and as the consequence can use the different links for navigation, or have the necessity in bigger annotation about the lecture etc.













Adaptive Educational Hypermedia System (AEHS) – is the specific Adaptive Hypermedia System, applied in the context of learning and consists of the document space, the model of a user, and the components of observation and adaptation. The tool that allows to create and hypermedia systems – tool for creating adaptive electronic textbooks (AET).

While conducting of the analysis of the available ALS, we detected a few more types. *Adaptive Learning Platform (ALP)* – is the platform that modifies the presentation of material in response to the results of pupils' activity, recording small data and using the educational analytics to ensure the individual adaptation. *Adaptive Deep Learning Platform (ADLP)* – is the platform that is built on the set of methods of machine learning and the theory of artificial neural networks that is based on the learning by feature / representation learning and not on the specialized algorithms for the specific tasks. *Computer Adaptive Educational Assessment (CAEA)* – is the platform that organizes the complicated adaptive testing, realizing the selection of test questions on the base of previous answers of a pupil and has the complicated model of assessment of the pupil's activity results. *Learning Objects Difference Engine (LODE)* according to the definition of the developer is the program of the innovative learning, courses and experience of learning that uses the mechanism of differences for ensuring of learning on the base of competences, the personalized and AL. The technology of this educational environment is built on the creation of objects with programs and courses integrating publisher content, open educational resources, faculty content and

other ed tech vendors' tools. The conducted review of the existing adaptive learning systems we will systematize in the Table 1.

Table 1. The existing adaptive learning systems.

System	Web-site	Type	Developed by	Year of dev.	Charges	System		
						Cloud	Mobile	Local
 Course Arc	coursearc.com	ALP	Bethany Meyer, Katie Egan	2015/2020	Trial/Pay	+	+	+
 Realizeit	realizeitlearning.com	ITS	DBA of CCKF	2007/2020	Pay	+	+	-
 Brightspace LeaP	d2l.com/products/leap	ALP	Desire2Learn	1999/2018	Trial/Pay	+	+	-
 Möbius	maplesoft.com/products/Mobius	ALP	Digital Ed	1998/2020	Pay	+	+	-
 WileyPLUS	wileyplus.com	ALP	John Wiley & Sons, Inc.	2000/2020	Demo/Pay	+	+	-
 Revel	pearsonhighered.com/revel/	ALP	Pearson	2012/2020	Pay	+	+	-
 Junction	junctioneducation.com	ALP	Junction education	2013/2019	Pay	+	+	-
 Smartwork5	wwnorton.com/smartwork5	AET	W. W. Norton	2012/2020	Pay	+	-	-
 MindTap	cengage.com/mindtap	LO DE	Cengage Learning	2009/2020	Pay	+	+	+
 InQuizitive	wwnorton.com/inquizitive	ALP	W. W. Norton	2000/2020	Free/Pay	+	-	-
 BARNES & NOBLE education	bnedcourseware.com	ITS	Barnes & Noble Education	2015/2019	Demo/Pay	+	-	-
 Smart Sparrow	smartsparrow.com	ALP	University of New South Wales	2010/2018	Trial/Pay	+	+	-
 Author	muzzylane.com	ITS	Muzzy Lane Software	2002/2020	Free/Pay	+	+	-
 OLI	oli.cmu.edu	ALP	William & Flora Hewlett Found.; Carnegie Mellon	2001/2019	Free/Pay	+	+	-
 Fishtree	fishtree.com	ALP	Fishtree	2012/2020	Free/Pay	+	+	-
 MindEdge	mindedge.com	AE HS	MindEdge, Inc	1998/2020	Pay	+	+	-
 Learning Objects	learningobjects.com	ALP	Washington, DC	2003/2020	Pay	+	+	-
 SL straighterline	straighterline.com	ITS	Straighterline, Inc.	2008/2020	Pay	+	+	-

System		Web-site	Type	Developed by	Year of dev.	Charges	System		
							Cloud	Mobile	Local
	Knewton	knewton.com	ALP	Jose Ferreira	2008/2019	Trial/Pay	+	+	-
	WebAssign	webassign.com	AET	Cengage Learning	2003/2020	Pay	+	+	-
	Omega Notes	omeganotes.com	ALP	Lang Enterprises LLC	2015/2020	Free/Pay	+	+	+
	ModCourse	modcourse.com	ALP	Little Bird Games	2014/2016	Free/Pay	+	-	-
	panOpen	panopen.com	AE HS	panOpen LLC	2013/2018	Pay	+	+	+
	Drillster	drillster.com	ALP	Drillster BV	2006/2020	Demo/Pay	+	+	+
	CogBooks	cogbooks.com	ITS	CogBooks, Ltd	2015/2020	Demo/Pay	+	+	-
	The Open Learning Initiative	oli.stanford.edu	ALP	Open Learning Initiative at Stanford University	2012/2020	Free/Pay	+	-	-
	SoftChalk Create	softchalk.com	ITS	SoftChalk LLC	2002/2020	Pay	+	+	-
	NWEA	nwea.org	ALP	Northwest Evaluation Association	1973/2019	Free/Pay	+	+	-
	iTutorSoft	itutorsoft.com	AD LP	Greater Washington DC (Vlad Goodkovsky)	2012/2019	Free	+	+	-
	GIFT	gifttutoring.org	ITS	U.S. Army Research Laboratory	2009/2019	Free	+	+	+

One of the biggest and functional adaptive systems nowadays is CogBooks. The courses, placed on the platform, are developed together with the scientists of universities. The company Knewton is known for the fact that it was one of the first to actively apply the technologies of analysis of data in the sphere of education. The adaptive educational platform that could be launched to any modern control system of learning process (LMS) was created as the result of this work. The methodology of Knewton is built around two main notions: the technologies of planning of educational trajectory and the complicated model of the student's assessment. Such approach differs dramatically from the majority of "adaptive applications", which indeed apply the adaptive approach to single point in which the students' knowledge is measured. The example of such "fairly adaptive" approach is the diagnostic exam, according to the results of which a computer defines what content will be shown to a student further on. The technologies of data mining and the personalization are used minimally here or are not used at all. One of the developers of the adaptive tests for monitoring is NWEA that

creates the adaptive tests for different goals. For example, the test MAP Growth is used for the periodic testing of pupils' knowledge of different subjects, while MAP Skills is recommended to be applied more often. Considering the adaptive learning systems let's research their territorial distribution. For this we will view the institutions of higher education at which the implementation and usage of the adaptive learning systems was carried out. The visualization of territorial distribution is demonstrated on the Fig. 1.



Fig. 1. The territorial distribution of the adaptive learning systems

According to the analysis of the distribution of the adaptive learning systems we make the conclusion that the systems acquired the widest spread on the territory of The United States of America. The adaptive learning systems acquired the big distribution in Canada (Revel, Möbius and Brightspace Leap). In Great Britain at University of Birmingham Möbius is applied in studies, Muzzy Lane Author is used at The University of Chicago Center in Delhi. Smart Sparrow is used in Australia at the University of New South Wales (UNSW Sydney) and at St. Petersburg University. Reviewing the system that was developed by Vlad Goodkovsky iTutorSoft (CLARITY) let's remark its usage at South-Ukrainian Nuclear Power Plant; Novo-Voronezh Nuclear Power Plant; US NAVY; Kursk Nuclear Power Plant; University of Virginia; Carney Inc and ScreenMentor Inc.

2.3 The results of review of the functional opportunities of the ALS

The type of every system was determined for better understanding of the functional opportunities of the systems of popular ALS. For determination of the type of adaptive system of learning we were guided by the following abbreviations: Intelligent Tutoring System (ITS), Adaptive Educational Hypermedia System (AEHS), Adaptive Learning Platform (ALP), tool for creating adaptive electronic textbooks (AET), Adaptive Deep Learning Platform (ADLP), Computer Adaptive Educational Assessment (CAEA), Learning Objects Difference Engine (LODE). Also by functional opportunities, which were the subject of research, we determined the usage of Natural language technologies (NLT), in particular the availability of technologies Natural language processing (NLP)

and Natural language understanding (NLU). To the significant factors, according to which the adaptive systems of learning were analyzed, also we reviewed the single-point adaptation (Sp) tra the continuous (C) adaptation. The analysis of the functional opportunities of the adaptive learning systems is provided in the Table 2.

Table 2. The review of the functional opportunities of the adaptive learning systems.

System	competency-based	Courseware Features				LMS Integration					NLT		Types of AL				
		Course Builder	Course Complete	Pre-made Course	Supplemental	Blackboard	Canvas	Brightspace by D2L	Moodle	Sakai	Schoology	NLG	NLP	single-point / continuous	adaptive learning	adaptive testing	complex valuation
CourseArc	-	+	+	-	+	+	+	+	+	+	+	-	-	C	+	+	+
Realizeit	+	+	+	-	+	+	+	+	+	+	+	-	-	C	+	+	+
Brightspace LeaP	+	+	+	-	-	+	+	+	+	-	-	+	+	C	+	-	-
Möbius	+	+	+	+	-	+	+	+	+	+	-	-	-	C	+	-	+
WileyPLUS	-	-	+	+	-	+	+	+	+	+	+	-	+	Sp	+	-	-
Revel	-	-	+	+	-	+	+	+	+	-	-	-	-	Sp	+	+	+
Junction	-	+	+	+	-	+	+	+	+	+	+	-	+	C	+	+	-
Smartwork5	-	-	-	+	+	+	+	+	+	+	+	-	-	C	+	+	-
MindTap	-	-	+	+	-	+	+	+	+	+	+	-	-	C	+	+	+
InQuizitive	-	-	+	+	-	+	+	+	+	+	+	-	-	C	+	+	+
BNED	-	+	+	+	-	+	+	+	+	+	-	-	-	C	+	+	+
SmartSparrow	-	+	+	-	+	+	+	+	+	-	-	-	-	C	+	+	-
Author	-	+	-	-	+	+	+	+	+	+	+	-	-	C	+	+	+
OLI	-	-	+	+	+	+	+	+	+	-	+	-	-	C	+	+	+
Fishtree	-	+	+	-	+	+	+	+	+	+	+	-	+	C	+	+	+
MindEdge	-	-	-	-	-	-	-	-	-	-	-	+	+	Sp	+	+	+
Learning Objects	+	+	+	+	+	+	+	+	+	-	-	+	-	C	+	+	-
Straighterline	+	-	+	+	-	+	+	+	+	+	+	-	-	C	+	+	-
Knewton	+	-	+	+	+	+	+	+	+	+	+	+	+	C	+	+	+
Web Assign	-	-	+	-	-	+	+	+	+	+	-	-	-	C	+	+	-
Omega Notes	-	+	-	-	-	-	-	-	-	-	-	-	-	C	+	-	-
ModCourse	-	+	+	-	-	+	+	-	+	-	-	-	-	C	+	+	+
panOpen	+	+	+	+	+	+	+	-	-	-	-	-	-	C	+	+	+
Drillster	+	+	-	+	+	-	-	-	+	-	-	+	+	C	+	+	-
CogBooks	-	+	+	+	-	+	+	+	+	+	+	-	+	C	+	+	-
SoftChalk Create	-	+	+	-	-	+	+	+	+	+	+	-	-	C	+	+	+
NWEA	+	+	+	-	+	+	+	-	-	-	-	+	+	C	-	+	+
iTutorSoft	+	+	-	-	-	-	-	-	+	-	-	-	-	Sp	+	+	-
GIFT	-	+	-	-	-	-	-	-	-	-	-	+	+	C	+	+	+

Researching the opportunities of mentioned adaptive learning systems we will address to Ratings company self-assessment, guided by the CWiC Framework [26] and systematize in the Table 3.

Table 3. The opportunities of the adaptive learning systems according to Ratings company self-assessment, guided by the CWiC Framework.

System	Courseware Features (Ratings by the CWiC Framework)					
	Adaptivity	Customization	Learner Autonomy	Socio-Emotional	Assessment	Collaboration
CourseArc	Low	High	Low	Low	Low	Low
Realizeit	High	High	Medium	Medium	High	High
Möbius	High	High	Low	Low	High	Low
Junction	High	High	High	Medium	High	High
Smartwork5	Medium	High	Low	Low	High	Low
InQuizitive	Low	High	Low	High	Medium	Low
BNED	Low	High	Low	Low	Medium	Medium
Smart Sparrow	High	High	High	High	High	Medium
Author	Medium	High	High	High	High	High
OLI	High	High	Low	High	High	Medium
Straighterline HE	Low	Low	Medium	Low	High	Low
Knewton	High	High	Low	Low	High	Medium
WebAssign	Low	High	High	Low	Medium	Medium
CogBooks	Medium	High	Low	Low	High	High

The characteristics according to which was researched the functional of adaptive systems of education was chosen Adaptivity (The content can be adjusted in relation to a learner's knowledge), Customization (Educators and course designers can alter learning or assessment content), Learner Autonomy (Learners can impact or augment instruction based on their choices), Socio-Emotional (Use of feedback and interventions based on a learner's social-emotional state), Assessment (The presence of academic structures and the capacity to assess learning in relation to them), Collaboration (Ability for learners and/or educators to engage with each other in the context of learning), each of which was ranked in accordance to the scale low, medium and high. According to the results of the research let's summarize that the adaptive learning systems have the wide functional in the building of individual educational trajectories that adjust to the educational needs of every person, thereby realizing the personified studies. The main reason of the creation and application of such systems is the fact that all people perceive information differently.

For some it is enough to read the paragraph once and for some a week of cramming is not enough. Using the system of adaptive learning it is possible to build the individual trajectory of education, what will adjust to the educational problems of every pupil, providing the best variant of the educational trajectory that realizes the personified individualized study. For example, the building of the individual trajectory of education in Knewton system reacts to the results of a separate student and his actions in the system in real time. The illustration of the principle of building of the individual trajectory is provided directly in “Knewton Adaptive Learning. Building the world’s most powerful education recommendation engine” [27, pp. 6-7]. Such approach enlarges the probability of the fact that a student will receive the right educational content at the necessary moment and will achieve the set aims. For example, if a student copes poorly with the definite set of questions, then Knewton can assume what topics, raised in this list of questions, turned out to be incomprehensible and offer him the content that will help to raise the level of understanding of precisely these topics.

3 Conclusion

According to the results of research we can make the conclusion that nowadays the adaptive learning systems only start the active development and gradual implementation. Even in the developed countries of the world such systems did not acquire the significant distribution and undergo the experimental approbation. Such systems, in comparison with the elaborations of previous generations, configure better and faster in the process of work, are characterized by the flexibility and openness to modifications that eventually allows ensuring of the individualization, personalization, personal-oriented approach in education. The algorithm of the adaptive learning systems assesses the results of every pupil in the mode of real time and depending on this adjusts its content, tempo, etc. The competence approach, orientation to the individual progress is laid in the basis of the functioning of such systems. Bearing in mind the above mentioned, we consider the studies of the theoretical principles of designing and implementation of the adaptive learning systems in the educational process, and also the development of methodic recommendations regarding the usage in the educational process to be relevant and promising.

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Personalized and Adaptive ICT-Enhanced Learning: A Brief Review of Research from 2010 to 2019

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Abstract. Personalized learning is an up-to-date trend of formal and informal education development. Its main peculiarity is the maximum consideration of the person's educational needs. Nowadays, personalized learning involves development of student model based on personal characteristics; customized learning content, as well as intellectual information and communication technologies. These approach is considered as adaptive learning. Research results in the field of personalized and adaptive learning are presented in numerous publications. Thus, it was decided to perform the search in Scopus and Web of Science Core Collection, as well as the electronic libraries of the Institute of Electrical and Electronics Engineers and Association for Computing Machinery. The study consisted of two stages: 1) search by a set of key phrases; 2) search by a custom search query. The results of the analysis of the generated sample by years of publication, countries of origin of authors, number of citations are presented in tables and diagrams. Moreover, the review of some significant publications is given, and main areas of further studies are detected such as, the examining of teachers' experience in the field of use adaptive learning systems.

Keywords: personalized learning, adaptive learning, review.

1 Introduction

Increasing attention to a person-centered learning approach, widespread use of information and communication technologies in formal and non-formal education become a factor of the intensive research in the field of learning individualization and personification. The scientific results are reflected in numerous publications. In particular, methodological approaches and aspects of using information and communication technologies for personalized learning are presented in [1; 2; 3; 4; 5; 6].

As Turčáni and Balogh mention, personalized learning recognizes learners' diversity, cognitive and physical differences and the overall individuality. It includes various learning styles and approaches: from focused on the educational content to focused on supporting the learners by communication, discussion, cooperation [7, p. 47-48].

So, it is important to study the current state of research of the problem by reviewing literature sources. It is a common method of analysis, so there are a lot of articles presenting the reviews of publications on various aspects of personalized and adaptive learning.

Akbulut and Cardak [8] made a content analysis of studies describing adaptive educational hypermedia (AEH) with a focus on learning styles. They searched publications from 2000 to 2011 in several electronic databases, namely Ulrich's Periodicals Directory, ISI Web of Knowledge, EBSCOhost Web, SpringerLink, ERIC, Google Scholar and others. For research purpose different key words and phrases were used, eg. "adaptive/adaptable e-learning", "adaptation", "personalized e-learning", "learning styles". Authors selected 70 papers of such types as peer-reviewed articles, full-text proceedings of international conferences, symposia and workshops, and dissertations in English. These publications were classified under several categories, namely Publication type, Main focus, Purpose, Study nature, Variables used for adaptivity, Learning style model, Student modeling, Tool for modeling, Tools for dynamic modeling, Research settings, Participants, Type of empirical studies, Data collection tools. As a result, authors identified some expectations of AEH using in education.

We examined some other papers dedicated to literature review on personalized learning and adaptive learning systems. A systematic literature reviews were conducted to study individual differences accommodating in adaptive learning systems (Nakic, Granic, and Glavinic [9]); using competence-based recommender systems (Yago, Clemente, and Rodriguez [10]); personalized electronic learning models as a combination of learning theories, techniques and tools (Jando et al. [11]); characteristics, applications, and evaluation methods of intelligent tutoring systems (Mousavinasab et al. [12]); personal traits in adaptive learning environment and learners' models (Normadhi et al. [13]); challenges in the online component of blended learning (Rasheed, Kamsin, and Abdullah [14]).

The main motivation which encourages us to conduct this study is necessity to define methodological foundations and appropriate means of development of personalized adaptive learning system for professional training at universities, within the research on request of the Ministry of Education and Science of Ukraine, registration number 0120U101970. To achieve this goal needs to select pool of theoretical and applied papers.

Furthermore, there are two research questions in our study. First, "are issues of personalized and adaptive ICT-enhanced learning up-to-date?". Second, "what are the ICT-means for personalization of learning?". This study was conducted through a review relating to personalized and adaptive ICT-enhanced learning of papers published from 2010 to 2019.

2 Methodology

In the course of our study, we relied on the methodological foundations of the literature review as a research method outlined in [15; 16; 17], as well as materials of scientific publications Akbulut and Cardak [8], Nakic, Granic, and Glavinic [9], Yago, Clemente, and Rodriguez [10], Jando, Meyliana, Hidayanto, Prabowo, Warnars, and Sasmoko [11], Afini Normadhi, Shuib, Md Nasir, Bimba, Idris, and Balakrishnan [13], Rasheed, Kamsin, and Abdullah [14].

We analyzed the scientific publications in the abstract and citation databases Scopus (<https://www.scopus.com>) and the Web of Science Core Collection (www.webofknowledge.com), as well as the libraries of the Institute of Electrical and Electronics Engineers (IEEE, <https://ieeexplore.ieee.org>) and the Association for Computing Machinery (ACM, <https://dl.acm.org/>). These electronic resources were selected since they contain international scientific sources of high impact-factor. In order to select the most up-to-date and thorough research, it was decided to introduce additional restrictions, namely: articles in periodicals and proceedings of scientific conferences, as well as books and parts of books published in 2010-2019.

Web services of Scopus and Web of Science Core Collection abstract and citation databases provide a strong search functionality. In particular, we used filtration by subject area / category. Since our research was mainly related to the educational process, the subject area "Social Sciences" was selected for search in Scopus, and the category "Education educational research" in Web of Science Core Collection. The search was performed under the Title, Abstract and Keyword fields.

On the first stage, in order to determine the general level of scientific interest in the field of adaptive and personalized learning, we conducted a search in three categories, which can be defined as: "*personalization of learning*", "*adaptation of learning*", "*information systems for learning*". In the process of keyword selection, we relied on works [9; 13; 18]. Three key phrases were selected for each area, namely:

- "personalization of learning": "personalized learning", "individual learning", "direct instruction";
- "adaptation of learning": "personalized e-learning", "adaptive learning", "intelligent tutoring";
- "information systems for learning": "personalized learning environment", "adaptive learning system", "intelligent tutoring system".

On the second stage, for the selecting of publications, which present the results of experimental studies in the field of adaptive learning systems, we composed a search query consisting of four parts, combined by the logical operator AND:

1. keywords to select publications that address adaptive and personalized learning: (*adapt* OR personali**);
2. keywords to select education related publications: (*education* OR "tutoring" OR instruction* OR course**);
3. keywords to select publications related to educational information systems: (*"learning environment" OR "learning system" OR "tutoring system"*);

4. keywords to select publications that show the results of surveying, questionnaire, and empirical studies and in the field of using adaptive learning systems: (*evaluat* OR empiric* OR experiment* OR survey* OR questionnaire*).

Given the specifics of the query language of databases, as well as the additional limitations pointed out, search queries were as follows:

for search in Scopus:

TITLE-ABS-KEY (adapt* OR personali*) AND TITLE-ABS-KEY (education* OR "tutoring" OR instruction* OR course*) AND TITLE-ABS-KEY ("learning environment" OR "learning system" OR "tutoring system") AND TITLE-ABS-KEY (evaluat* OR empiric* OR experiment* OR survey* OR questionnaire) AND (LIMIT-TO (DOCTYPE,"ar") OR LIMIT-TO (DOCTYPE,"cp") OR LIMIT-TO (DOCTYPE,"ch") OR LIMIT-TO (DOCTYPE,"bk")) AND (LIMIT-TO (SUBJAREA,"SOCI") OR EXCLUDE (SUBJAREA,"MEDI") OR EXCLUDE (SUBJAREA,"HEAL")) AND (LIMIT-TO (PUBYEAR,2019) OR LIMIT-TO (PUBYEAR,2018) OR LIMIT-TO (PUBYEAR,2017) OR LIMIT-TO (PUBYEAR,2016) OR LIMIT-TO (PUBYEAR,2015) OR LIMIT-TO (PUBYEAR,2014) OR LIMIT-TO (PUBYEAR,2013) OR LIMIT-TO (PUBYEAR,2012) OR LIMIT-TO (PUBYEAR,2011) OR LIMIT-TO (PUBYEAR,2010))

for search in Web of Science Core Collection:

TS=((adapt* OR personali*) AND (education* OR "tutoring" OR instruction* OR course*) AND ("learning environment" OR "learning system" OR "tutoring system") AND (evaluat* OR empiric* OR experiment* OR survey* OR questionnaire))

Refined by: WEB OF SCIENCE CATEGORIES: (EDUCATION EDUCATIONAL RESEARCH) AND DOCUMENT TYPES: (ARTICLE OR BOOK CHAPTER OR PROCEEDINGS PAPER)

Timespan: 2010-2019. Indexes: SCI-EXPANDED, SSCI, A&HCI, CPCI-S, CPCI-SSH, BKCI-S, BKCI-SSH, ESCI

Search results are presented through tables and diagrams.

3 Research Results and Discussion

To answer the first research question, "are issues of personalized and adaptive ICT-enhanced learning up-to-date?", the search in electronic libraries and databases was done.

Analysis of data collected through selecting publications in abstract and citation databases, as well as electronic libraries by the key phrases "*personalized learning*", "*individual learning*", "*direct instruction*", "*personalized e-learning*", "*adaptive learning*", "*intelligent tutoring*", "*personalized learning environment*", "*adaptive learning system*", "*intelligent tutoring system*", leads to the conclusion that over the last decade, researchers have paid considerable attention to the theoretical and practical aspects of personalized and adaptive learning, in particular to using of information and communication technologies for provision of education adaptability (see Table 1).

Table 1. Generalization of search results.

Key phrases	Resource			
	IEEE Xplore® Digital Library	ACM Digital Library	Scopus	Web of Science Core Collection
personalized learning	411	550	720	448
individual learning	399	709	1056	596
direct instruction	26	171	505	312
personalized e-learning	70	29	65	28
adaptive learning	1351	972	782	385
intelligent tutoring	860	973	916	523
personalized learning environment	22	31	75	25
adaptive learning system	83	46	139	45
intelligent tutoring system	291	348	859	235

The data got from the Scopus and Web of Science Core Collection abstract and citation databases reveal the dynamics of scientists' publication activity in the field of personalized and adaptive learning by years. The results are given in the Table 2 and Fig. 1-3. We can state a stable scientific interest for these issues. In particular, the number of publications on most of the key phrases analyzed significantly increased in 2014.

Table 2. Distribution of publications on problems of personalized and adaptive learning by years.

Key phrase	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Web of Science Core Collection										
personalized learning	19	15	24	27	23	49	88	86	72	45
individual learning	52	43	46	50	40	82	76	82	71	54
direct instruction	15	21	19	20	17	46	35	42	53	44
personalized e-learning	2	2	2	2	4	3	3	2	5	3
adaptive learning	25	20	18	28	24	35	65	68	55	47
intelligent tutoring	45	24	29	42	41	45	99	79	54	65
personalized learning environment	2	1	1	2	1	2	5	4	4	3
adaptive learning system	0	3	2	4	1	7	8	2	10	8
intelligent tutoring system	22	8	13	18	14	27	47	31	24	31
Scopus										
personalized learning	46	35	55	50	48	78	75	91	110	132
individual learning	97	99	100	97	96	124	95	108	112	128
direct instruction	40	31	49	46	38	60	44	50	65	82
personalized e-learning	7	5	6	8	6	5	6	3	8	11
adaptive learning	63	55	52	63	57	70	99	93	123	107

Key phrase	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
intelligent tutoring	92	68	81	89	90	89	122	98	94	93
personalized learning environment	8	5	6	8	5	9	10	7	7	10
adaptive learning system	4	5	9	16	15	11	21	17	22	19
intelligent tutoring system	80	63	76	86	83	84	114	90	92	91

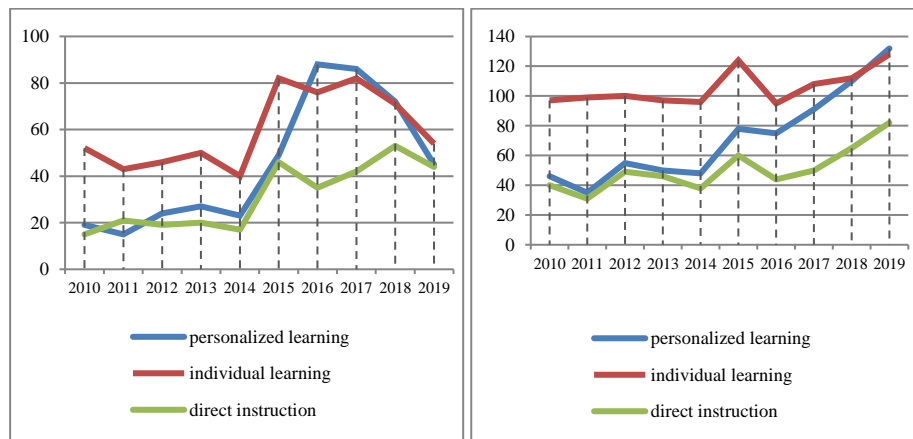


Fig. 1. Dynamics of publication activity on the problems of personalized and individual learning, according to Web of Science Core Collection (a) and Scopus (b) abstract and citation databases (accessed March 25, 2020).

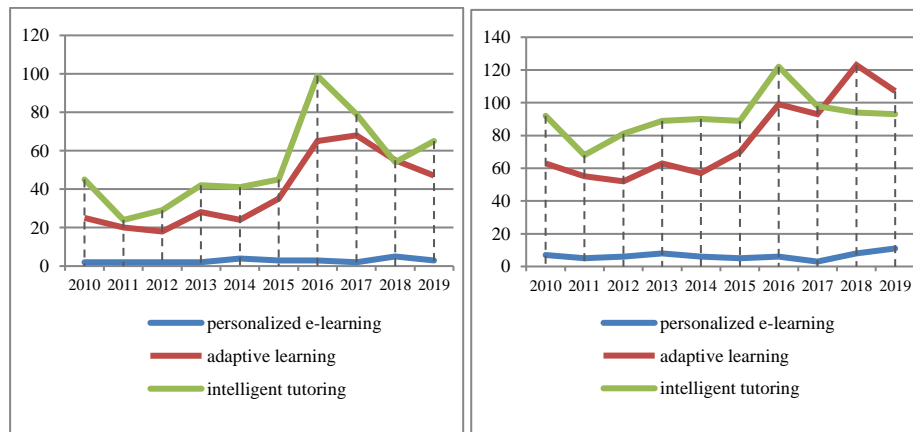


Fig. 2. Dynamics of publication activity on the problems of personalized e-learning, adaptive learning and intelligent tutoring, according to Web of Science Core Collection (a) and Scopus (b) abstract and citation databases (accessed March 25, 2020).

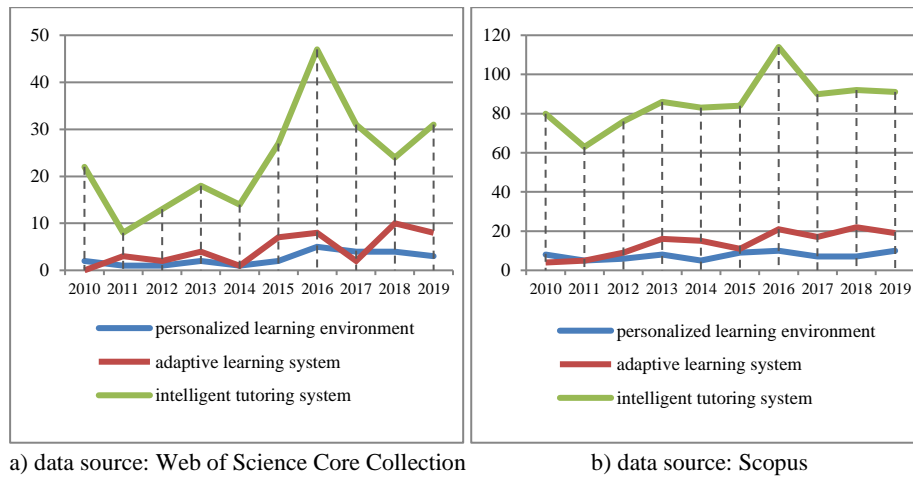


Fig. 3. Dynamics of publication activity on the problems of personalized learning environment, adaptive learning system and intelligent tutoring system, according to Web of Science Core Collection (a) and Scopus (b) abstract and citation databases (accessed March 25, 2020).

The Web of Science Core Collection and Scopus abstract databases also provide an opportunity to analyze the distribution of authors by country. Based on the analysis of relevant data, we can conclude that these problems are relevant for educational systems of different countries. The most scientists represent the United States of America. The leaders' list includes researchers from China, Spain, Germany. In the Table 3, three countries with the highest authors of publications percentage are shown for each of the key phrases.

Table 3. Distribution of publications on personalized and adaptive learning by country.

Key phrase	Percentage of the total number of authors of publications indexed in the abstract database		
	1st	2nd	3rd
Web of Science Core Collection			
personalized learning	USA 24.8%	China 18.3%	Spain 7.8%
individual learning	USA 13.4%	Germany 9.9%	China 6.0%
direct instruction	USA 36.9%	Indonesia 6.7%	Germany 6.4%
personalized e-learning	Australia 14.3%	Greece 14.3%	China 10.7%
adaptive learning	USA 19.2%	Taiwan 7.5%	Spain 7.3%
intelligent tutoring	USA 36.1%	Taiwan 8.0%	Spain 6.5%
personalized learning environment	USA 20.0%	Spain 12.0%	Greece 8.0%
adaptive learning system	USA 17.8%	Taiwan 17.8%	China 13.3%
intelligent tutoring system	USA 34.0%	Spain 8.5%	Canada 8.1%
Scopus			
personalized learning	USA 24.2%	China 13.6%	United Kingdom 8.1%

Key phrase	Percentage of the total number of authors of publications indexed in the abstract database		
	1st	2nd	3rd
individual learning	USA 19.3%	Germany 11.1%	United Kingdom 9.8%
direct instruction	USA 47.7%	Australia 6.3%	Canada 5.5%
personalized e-learning	Greece 10.8%	Spain 9.2%	United Kingdom 9.2%
adaptive learning	USA 22.6%	China 9.3%	Taiwan 6.6%
intelligent tutoring	USA 39.7%	Germany 6.6%	China 5.8%
personalized learning environment	USA 18.7%	Germany 9.3%	United Kingdom 6.7%
adaptive learning system	USA 19.4%	China 15.1%	Taiwan 7.9%
intelligent tutoring system	USA 39.7%	Germany 6.5%	China 5.9%

The analysis of publications indexed by Scopus and Web of Science Core Collection by criterion of authors' affiliations also shows that the United States is the leader (Scopus – 12.3%; Web of Science Core Collection – 11.0%).

Selecting of papers in electronic libraries and abstract databases within the search query "*adapt * OR personali **) AND (*education * OR "tutoring" OR instruction * OR course **) AND ("*learning environment" OR "learning system" OR "tutoring system"*) AND (*evaluative * OR empiric * OR experiment * OR survey * OR questionnaire*)" gave such results: IEEE Xplore® Digital Library – 402; ACM Digital Library – 3215; Scopus – 1280; Web of Science Core Collection – 573. Most of these materials have been published in influential international scientific journals, including Computers and Education, International Journal of Artificial Intelligence in Education, International Journal of Emerging Technologies in Learning, Interactive Learning Environments, British Journal of Educational Technology, Educational Technology & Society.

The distribution of publications by years according to Scopus and Web of Science Core Collection is given in Table 4 and shown in Fig. 4. Note, that the number of publications indexed in Scopus is gradually increasing, and the Web of Science Core Collection is changing slightly.

Table 4. Distribution of publications on problems of application of adaptive learning systems by years.

Data source	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Scopus	88	91	109	124	120	142	140	140	153	173
Web of Science Core Collection	5	3	6	4	3	12	12	6	8	12

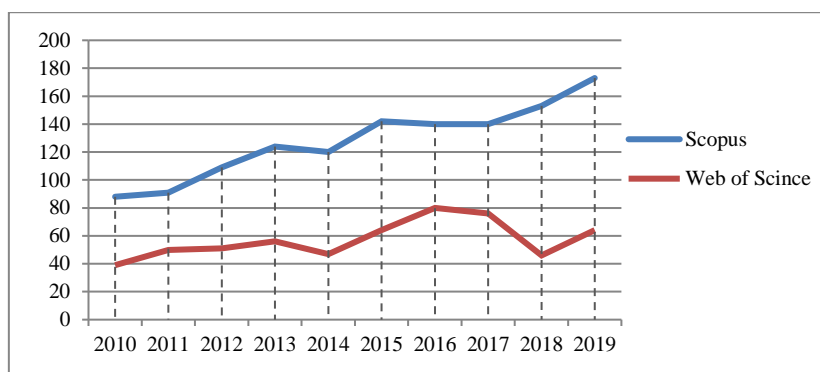


Fig. 4. Dynamics of publication activity on the problems of using adaptive learning systems personalized and adaptive learning according to Web of Science Core Collection (a) and Scopus (b) abstract and citation databases (accessed March 25, 2020).

One of the indicators of the interest of scientists in the presented materials, as well as the degree of influence of these publications in the field of research on the problems of adaptive learning in the educational process is their citation. The distribution of publications selected by search query by the number of citations is given in Table 5. The table is based on Scopus and Web of Science Core Collection data, so the number of citations in materials indexed in Scopus and Web of Science Core Collection is taken into account.

Table 5. Distribution of publications on problems of using adaptive learning systems by number of citations.

Data source	0 citations		1 – 49 citations		50 – 99 citations		100 or more citations	
	number	%	number	%	number	%	number	%
Scopus	352	27.5	876	68.4	38	3.0	14	1.1
Web of Science Core Collection	271	47.3	284	49.6	14	2.4	4	0.7

The findings of the studies implied that scientists are interested in issues of personalized and adaptive ICT-enhanced learning. So, we can state their significance for theory and practice of education.

To answer the second research question "what are the ICT-means for personalization of learning?", we examined some scientific papers devoted to using ICT for personalization of learning from the list selected on the previous exploring stage.

In [19], Su J-M. develops the a rule-based self-regulated learning (SRL) assistance scheme to intelligently facilitate personalized learning with SRL-based adaptive scaffolding support for learning computer software [19, p. 536]. He defines five adaptive scaffolding strategies and rule sets which are corresponding to planning, controlling, monitoring, and reflecting phases [19, p. 540]. Moreover, researcher describes intelligent learning environment built on these strategies, and gives examples of rule sets use. Through an experimental research, he points out advantages of using approach

offered. In particular, one of them is the scaffolding strategies can be manageable and extensible to support different learning subjects of computer software courses [19, p. 553].

In [20], Rohloff, Sauer, and Meinel discuss the problem of content and learning paths personalization in Massive Open Online Courses (MOOC). They state, that MOOC platforms are oriented on providing knowledge numerous learners. But, this approach is not very effective, and a lot of learners are not achieve their educational goals. Researchers offer tools to integrate personalized learning objectives into MOOC platform and facilitate students activities. Through the special interface, learners select learning objectives which are subsequently supported by guiding the learning with respect to the selected objective [20, p. 9].

In [7], Turčáni and Balogh are considering a methodology for creating a personalized e-course with the possibility of adapting to the learner in a special environment. They offer an AdaptiveBook module for LMS Moodle which collects data about students' activities and helps to build personal learning way.

A recommendation module of an adaptive and intelligent web-based programming tutoring system – Protus is described in [21]. As Klačnja-Milićević et al. state, tutoring systems can contain two categories of adaptivity tools: (1) adaptive hypermedia for course adaptation to learners' individual learning styles; (2) recommendation techniques to suggest the most appropriate learning activities to learners [21, p. 886].

The recommender framework offered by researchers contains three modules: (1) a learner-system interaction module, which gathers data of learners activities to build appropriate models; (2) an off-line module, which recognizes learners' goals using learner models; (3) a recommendation engine for producing a recommendation list [21, p. 888]. To investigate learning styles across four dimensions (Information Processing, Information Perception, Information Reception, Information Understanding), authors use data collection tool - Index of Learning Styles by Felder and Soloman [21, p. 889]. To evaluate benefits of using this recommendation module, researchers performed an experiment while studying programming. They conclude, that experimental results show positive effect of using proposed module.

Some other approaches to personalization of learning are considered in [22; 23; 24; 25; 26].

The following conclusions can be drawn from the results of the analysis:

- a person-centered approach is well developed in educational theory and practice. However, researchers are looking for new ways to implement it in order to achieve the highest degree of accordance learning content and means to person needs and opportunities and to provide conditions for lifelong learning;
- personalized and adaptive learning envisages the organization of the educational process when a comprehensive study of learner is carried out, then a model of one's possible development is constructed, and subsequent influences and interactions are built taking into account this non-static editable model;
- development of learner model is based on data about the learning style and other personal characteristics. Its collecting and further processing are complex process

that requires the involvement of specialists in various scientific fields, as well as the use of information and communication technologies;

- organizing the distance learning process updates research on the issues of adaptive learning systems, among which we consider it advisable to highlight areas such as: improving the functionality of existing learning management systems, including the extended Moodle platform, to provide them with the means of personalizing learning (student analysis, personal characteristics) formation of individual educational routes, adaptive delivery of educational content and assessment, etc.); professional training of specialists (psychologists, teachers, tutors) for the application of these systems in formal and non-formal education institutions.

At the end, it is necessary to emphasize that individualized and adaptive learning have an important significance for life-long learning development. There are some reasons of this statement. Firstly, these approaches are based on learning styles models, and suppose satisfaction of persons' educational needs in different circumstances. Secondly, using information and communication technologies helps to give access to learning to widespread strata of the population.

4 Conclusion

The article presents the results of studying the state of research into the problem of organizing personalized and adaptive learning, as well as the use of adaptive learning systems. The study was conducted using the method of extensive search in electronic databases.

The analysis covered scientific publications for the years 2010-2019, presented in the abstract and citation databases Scopus and Web of Science Core Collection, as well as the electronic libraries of the Institute of Electrical and Electronics Engineers and Association for Computing Machinery. The study consisted of two stages: 1) search for a set of key phrases: "*personalized learning*", "*individual learning*", "*direct instruction*"; "*personalized e-learning*", "*adaptive learning*", "*intelligent tutoring*"; "*personalized learning environment*", "*adaptive learning system*", "*intelligent tutoring system*"; 2) search on a custom search query (*adapt* OR personali**) AND (*education* OR "tutoring" OR instruction* OR course**) AND ("*learning environment*" OR "*learning system*" OR "*tutoring system*") AND (*evaluat* OR empiric* OR experiment* OR survey* OR questionnaire*). The results of the analysis of the generated sample by years of publication, countries of origin of authors, number of citations are presented in tables and diagrams.

The resulting sample covers publications in influential scientific publications. The refinements applied (time period, databases, key queries, search categories, etc.) limit its scope and facilitate processing, but narrow the analyzed area somewhat.

Taking into account the above perspective areas of research, further intelligence is aimed at conducting a systematic review of literary sources, which presents the experience of teachers in the use of adaptive learning systems, as well as studying the level of preparedness of teachers and higher education students in the field of knowledge "Education / Pedagogy" in their use in educational process.

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A Method to Ensure the Effectiveness and Attractiveness of E-Learning. Human-Oriented Systemic Ergonomic Approach

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Abstract. The article deals with the problems of the low efficiency of e-learning systems. We reveal the main ergonomic problems of computer systems for training and propose the concept of a man-system approach to the creation of e-learning systems. We have developed a method and information technology for optimizing man-machine dialogue interaction, taking into account the characteristics of a particular person, working in the e-learning system.

Keywords: e-learning, human-operator, ergonomics, educational environment, optimization, information technology, agent-manager, cyberspace.

1 Introduction

The introduction of computers has completely changed the educational process in schools, universities, as well as the processes of training and retraining of employees of firms and corporations [1-5]. Learning becomes continuous (both throughout life and throughout the day)[6-8]. People spend hours on a computer or mobile device daily[1,7,9]. You can study, take tests and exams, being thousands of kilometers from the university campus[1,10]. Even the defense of the thesis can be carried out remotely.

For these purposes[11-15]:

- Expensive equipment is purchased.
- Powerful databases and repositories are created.
- Organized are:
 - Technical support groups.
 - Scientific laboratories of distance learning, virtual and augmented reality.
 - Projects of remote access to unique technical equipment to study complex objects and conduct technical experiments and medical operations.

Thus, recent years can be associated with a revolutionary change in technical, software and information support, with a jump in technology, including artificial intelligence and an increase in capital investment in education[16-20].

2 Problem Statement

Despite the sound statements made by many universities about the victory of the concept of “paperless education”, the return on investments does not correspond to the expenditures of financial, technical and human resources[1,21-26].

The expected massive “world” leap in improving the quality of students' knowledge did not happen[27]. Moreover, there is a tendency towards a decrease in the quality of fundamental and natural science training (physics, mathematics, chemistry, biology, etc.)[28].

Students unlearn how to think and solve complex problems (if you have a smartphone with a calculator or a computer with a modeling program at hand).

The ability to explain the result, to analyze cause-effect relationships is reduced[15,22,28].

In the field of humanitarian training, the thoughtless unsystematic mass use of computer training leads, for example, to “coaching for tests” the journalist who is afraid and cannot work “live”, etc.[1,15].

Twenty years ago, the author of this article was the head of the project for the introduction of information technology for the management of the educational process at the Theological Academy (Sergiev Posad) and defended the concept of “maximum computerization of the educational process”. At the same time, the administration has proposed the concept of “intelligent automation”, figuratively explaining this by saying that a “robot priest” is unlikely to be useful in the field of serving God and People. (Of course, this is a unique but instructive story).

Often unsystematic informatization without focusing on a person gives only harm. We even discuss a problem like “when the computer kills us”[29]! At the same time, many researchers are concerned about the harmfulness of the Internet and social networks associated with the described problem. A number of scientists even set the task of ensuring cyber-security of e-learning and the health of students[24,29,32-34]. Modern people cannot and do not want to work with complex software environments and training materials that are not adaptable to their needs and features[2,3,19,27].

Thus, the task of this work is defined as follows: to identify the reasons for the low efficiency of e-learning and to develop a method that provides flexible adaptation of electronic educational environments to the psychophysiological and motivational characteristics of people working with the system, based on advanced achievements in engineering psychology, ergonomics, and the theory of adaptive systems.

3 Research of the Problem and Development of Methodological Basis for its Solution

3.1 Reasons for the Low Efficiency of E-Learning. Students Survey Results

Very often, students drop out of school because “they don’t get what they expect from the system.” We organized a special survey of students (Ukraine, Poland, Belarus,

Kazakhstan and Germany - 389 students in total) about their assessment of the reasons for the low efficiency of e-learning systems (Table 1).

Table 1. Reasons for undersatisfaction of students by electronic training technologies (average percentage of students reporting this reason as the main one)

<i>The complexity and imperfection of the learning environment</i>	<i>Undergraduate</i>	<i>Master's</i>
The difficulty of establishing a dialogue with the teacher to solve problematic issues	27.3	23.0
Inability to flexibly change the structure of the dialogue	25.1	20.0
Problems with modality, inconsistency of the presentation of information to the style convenient for the student	19.5	17.4
The inability to flexibly change the complexity of the material (depending on motivation and level of preparedness)	8.8	17.2
Lack of ability to evaluate quickly possible learning outcomes (to predict the time spent and assessment)	7.9	11.9
Lack of uniform standards for learning management	6.2	3.3
Errors, poor formatting, color gamut, etc.	3.1	3.0
Low flexibility to enable self-monitoring of the learning process and error explanations	1.1	3.3
Etc.	1.0	0.9

These results allowed us to find “painful” problematic issues that scientists and practitioners need to work on.

3.2 Development of a Methodology for an Ergonomic Approach to the Design of an Information Learning Environment

Disappointing assessments of existing e-learning technologies are forcing scientists and developers to turn to the ergonomic methodology of complex systems “man-technology-environment”[35-40].

Today, there is an opinion that the operator is a person who controls the technological process or watches the target on the radar screen, etc. Moreover, engineering psychology and ergonomics are mainly engaged in ensuring their comfort. At the same time, it is subjected to no less influence of negative factors, including stress than the operator managing the blast furnace or the call center operator. Only the nature of these negative influences is completely different. In this regard, when developing e-learning systems, it is necessary not to mechanically accumulate training electronic materials, but to design individual interactive training procedures that can flexibly adapt to a particular operator and environmental conditions.

In science, there are the following concepts for taking into account the characteristics of man and technology:

- Technical approach (today prevails in electronic education).
- Equal-element approach.
- Humanitarian approach (a person is at the forefront, technical features are not taken into account).

- human-system approach (man is the main element, but working in a specific system and environment, the features of which should be taken into account).

Obviously, it is necessary to reorient in the models of creating e-learning, switching from a technical approach to a human-system approach.

Using the principles of ergonomics and a human-system approach can dramatically change the situation with the attractiveness and effectiveness of e-learning. However, this is due to a lot of scientific, technical and organizational work.

4 Organization of Works for the Creation of Adaptive Human-Machine Training Systems

4.1 Creation of Prerequisites

Adaptive e-learning technology is possible only in the conditions of a developed electronic university management system [41] with:

- Developed database system and documentation of the learning process and outcomes.
- Unified electronic document management system

4.2 Technology for the Development and Certification of Electronic Training Modules

Preparation of training modules should not be entrusted only to the teacher. A whole group is being created, including (except for leading teachers):

- Content specialists.
- Designers, videographers.
- Programmers.
- Testers.
- Ergonomists.

Module requirements:

- For the same educational material, alternative modules are developed that focus on different styles of information presentation, for example:
 - Predominantly text.
 - Predominantly graphics.
 - Using audio and video.
 - “From general to particular”.
- The module should be assembled from individual elements (or submodules) as a “designer” or “nesting doll”: this means the level of complexity of the material (which will be offered to the student in the future depending on motivation, preparedness and time reserve):
 - Low.
 - Medium.
 - High.

- Each submodule is associated with several options for self-diagnosis or self-monitoring (with varying degrees of accuracy), which are turned on or off, depending on the available time resource.
- Each submodule is assigned a dialogue procedure with an explanatory component, which is turned on or off, depending on the results of self-monitoring and the time resource.
- Each module is assigned its:
 - Formal model describing its properties.
 - Functional networks [35,36,38] to describe the structure of the dialogue.
 - Mathematical models for predicting the time spent and the amount of points gained as a result of the dialogue.

The developed modules for inclusion in the database of training materials must undergo examination and certification procedures.

Special groups are created for this purpose:

- A group of experts.
- A working group (analysts, cognitologists, managers, and technical personnel).

Thus, evaluation criteria are created, some of which are given in the article [42] and a bank of mathematical methods and interactive procedures for processing expert estimates.

The idea of a certification system based on the principles of multicriteria assessment “on the scale of a thermometer with a slider” and fuzzy logic [42] is shown in Fig. 1

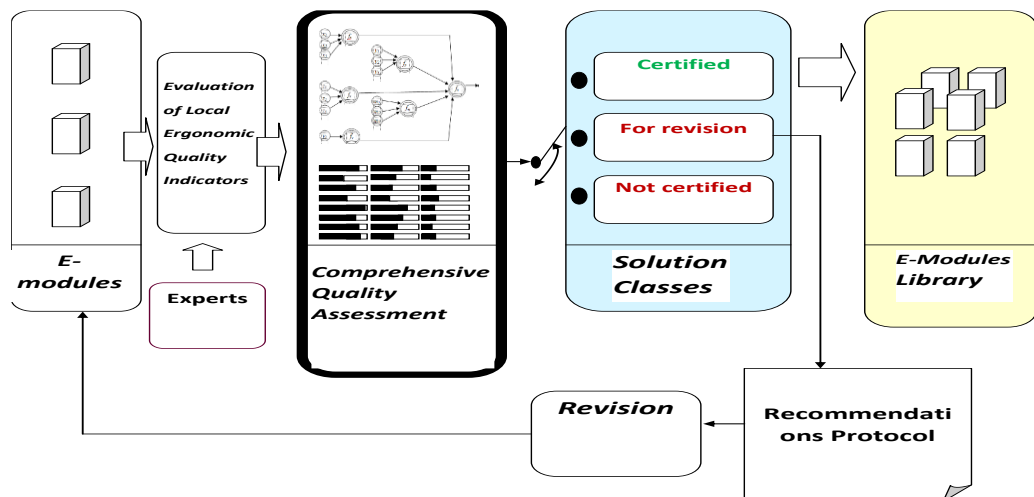


Fig.1. Certification of e-modules in the e-learning system. Functioning principle

Thus, only certified training modules that meet all the requirements relevant to the system are allowed to operate.

4.3 Study of Characteristics and Maintaining Models of Trainees (Operators)

For each system operator are determined:

- H1- Psychophysiological characteristics.
- H2- Learning Styles (desired).
- H3- Level of motivation (for discipline).
- H4- Preparedness for the study of discipline.
- H5- Functional Status (current).
- H6- Results (“history”, protocol) of all previous sessions of working with the system (which module was studied, how much time was spent, what were the results of self-monitoring and final control).
- To determine the characteristics of H1 and H2, computer diagnostic tools are stored in the database of the university management system. Such testing is carried out once, and the results are entered into the database of user models of the system and are used to adapt to each specific person..
H3 and H4 are determined before starting the study of discipline.

H5 is constantly monitored (after 10-30 minutes of operation in the system).

H6 is ongoing. The results are required to predict the reliability and timing of the implementation of elementary learning operations both for a given student and for others.

4.4 Information Support for Adaptive Interactive Learning Processes

The system “man-equipment-environment”, which we analyze, for making optimal decisions should be described in all necessary “sections”. These include:

- Modules.
- Students.
- Hardware and software.
- Communication channels.
- Resource constraints.

We describe the entire list of such necessary “sections” (there are more than 50) and, accordingly, the databases that we have developed in [37,43,44].Such information is required to generate the initial data necessary for assessing the likely learning outcomes and time spent in each specific situation in order to offer optimal interactive learning technology.

4.5 Method for Evaluating the Effectiveness of Learning and Cognitive Activities and Optimizing Dialogue Interaction

In order to conduct an assessment, the system builds a functional network [35,36,38] that describes the dialogue interaction and, using the mathematical models that we have developed for the probability of error-free execution of procedures and time costs [36,38,45], makes a forecast of the results and proposes an adjustment of the learning technology. Such adjustment is carried out according to the results of the study of each submodule.

4.6 Program-Manager to Manage the Learning Process

To manage the adaptive dialogue process, a special program has been developed that on-line solves a number of optimization problems for choosing the structure of dialogue interaction (Fig. 2).

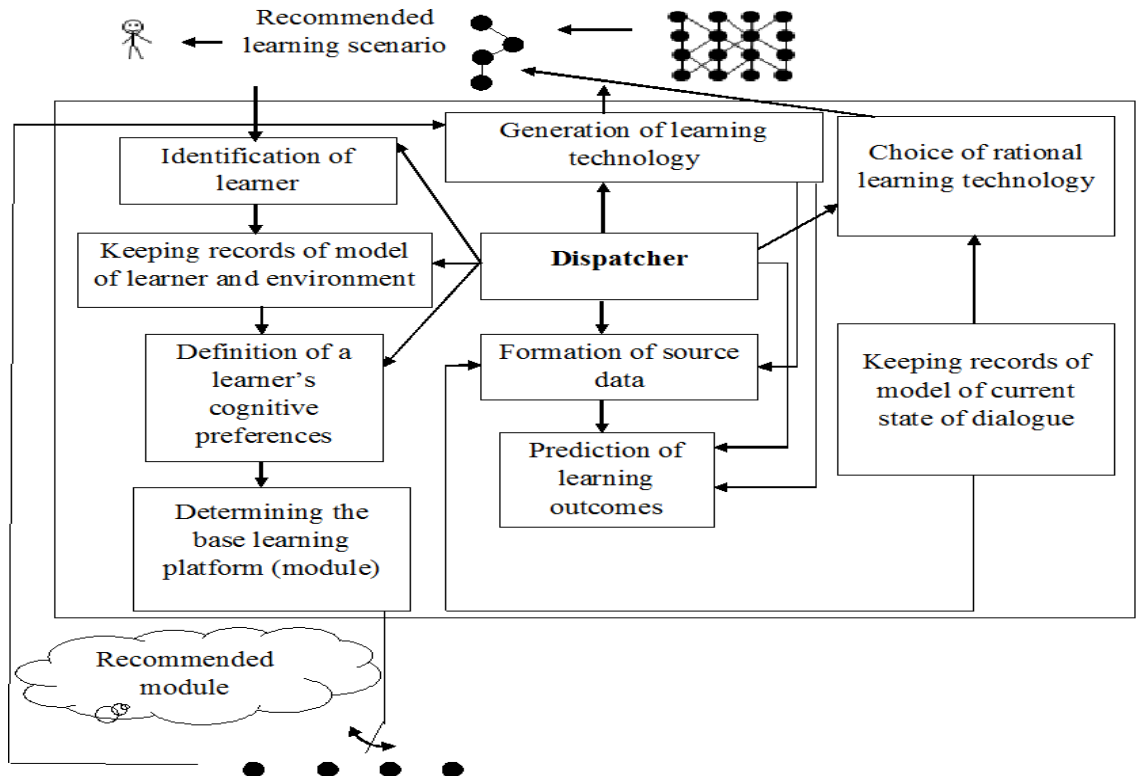


Fig.2. Manager for e-learning: functioning principle

The operator model is used for:

- Selection of a basic module (providing maximum cognitive comfort)
- Formation of initial data on the characteristics of performing elementary actions (the approximation problem is solved using all the data on training sessions of all users on which a special neural network was trained).

The initial data generated in this way are sent to the functional network, which makes it possible to predict the result and adjust the learning technology.

5 Approbation

We used this method in the framework of complex projects for the introduction of computer control systems at 20 universities of Ukraine (Kharkiv, Kremenchug, Vinni-

tsa, Sumy, Kryvyi Rih and other cities) and confirmed its effectiveness. Let us show just one indicator (for Sumy Agrarian University, Ukraine) for example [41]:

- In 2018, the average grade point at the Faculty of Agriculture was 72.1, and after the introduction of the system, it was 81.6 (on a 100-point scale).

The percentage of students refusing to use e-learning technology decreased from 25.8 percent to 7.0 percent.

6 Conclusion

The effectiveness of existing e-learning projects does not match the efforts and resources expended. Students do not want to work with uncomfortable and non-adaptive learning systems. The revealed list of claims to modern e-learning systems made it possible to justify the need for a transition to the human-system principle of designing such technologies. The transition to adaptive learning becomes possible if the system is described in the required sections and the corresponding databases are created, as well as if the functional network is used as a dialogue model. The adaptation process is reduced to the sequential solution of a number of optimization problems and can be implemented in the environment of a specially developed agent-manager.

Using the proposed technology can significantly improve the quality of the educational process and the attractiveness of e-learning.

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ICT evolution: from single computational tasks to modeling of life

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Abstract. The paper discusses the model of ITC evolution from viewpoint of the ratio of the number of devices and served users. The current stage of such an evolution is considered as wearable and modeling one. Special attention is paid to modeling and simulation (M&S) as an important trend in education/training for the business and industry. The new approach in its use in context of cloud-based technologies is proposed: Modeling and Simulation as a Service (MSaaS). The general architecture is proposed for consideration.

Keywords: ICT, aviation safety, astrophysics, database.

1 Introduction

As experts noted in 2017, “As we embark on the Fourth Industrial Revolution, it is clear that technology will play a central role in almost every aspect of our lives. Research by the World Economic Forum has estimated that 65% of primary school children will find themselves in professions that are not there today. By 2020, it is estimated that there will be 1.5 million new digitized jobs worldwide. At the same time, 90% of organizations now have a lack of IT skills, while 75% of teachers and students feel that there is a gap in their ability to meet the skills requirements of the IT workforce”[1]. The Davos’ World Economic Forum in January 2020 raised the question of the School of the Future: what it would be, in particular, the need to identify new models of education for the fourth industrial revolution [2], as the development and fulfillment of trends in the current stage of educational informatization [3] in the digital transformation of the learning environment [4].

It is clear that the solution of this problem requires certain resources, in the information age - digital [5], taking into account age-specific features of cognitive abilities at micro-age intervals [6], use of adequate methodological (first of all, mathematical) apparatus [7] for forecasting and appropriate choice optimal tools and adaptation of educational resources to the individual capabilities of the education seeker [8]. Appropriateness of the tools used can be estimated using substantiated criteria [9] and techniques [10].

According to the experts, “Higher human-machine interaction with new technologies will increase productivity but require different, often higher skills, new technological interfaces, different pay patterns in some cases, and different types of business and employee investment skills” [11, p.7]. Appropriate changes meet business requirements and need to be applied in education process effecting adaptive learning systems [12] and optimizing individual mental efforts [13].

Purpose. To develop the model of the ICT transformation from shared access computers to e-learning tools and technologies.

2 Methodology

The model of transformation of the digital education can be presented as evolutionary stages with corresponding types of digital tools and directions of support for the education process (Fig.1).

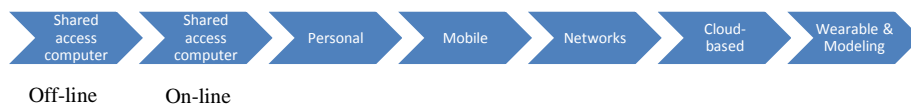


Fig.1 Evolutional stages with corresponding types of digital tools and directions of support for the education process

If the first stage can be described as “one shared access computer for many users” working off-line. The next stage had a new feature: possibility for a user to work on-line (mini-computers). The next stage of ICT evolution dealt with personal computers that became later smaller and mobile.

Networks provided users with extended possibilities, unlimited from point of view an access to different resources. Their development was a transformation into cloud-based resources, friendlier end extended for users’ needs.

The last stage, that we live on, can be characterized as much more flexible and person-oriented. The appropriate tools provide a user with opportunity to live and to act in the synthetic environment (virtual, augmented, mixed etc.), as well as provide opportunity for adaptive learning and construction of the personal trajectory of teaching [14]. Teaching is transforming from obtaining a set of facts or prescribed knowledge into the search of knowledge needed for the learner and synthesis of such knowledge by the learner himself/herself by using wide spectrum of tools. Because the amount of facts and knowledge becomes crucial every day, the search as such became not enough. Modeling and simulation give new opportunity to explore the world [15].

3 Results and Discussion

It is known that data interpolation for use in predictive models of object description and extrapolation have significant differences in the application of models to humans, not technical products, because humans have significant psychophysiological, psy-

chological, educational and other differences, because reliability and robustness of models to the effect of "noise" becomes of particular importance: their application to objects whose parameters are significantly different from those included in the training sample of the model under which the model is built. As a result, the question arises as to the optimality of the models by the criteria of prediction accuracy, reliability and robustness.

"It must be understood that not only new means and opportunities arise, but a digital transformation of the human life and human activity that was actively discussed at the Davos Forum in 2019. First of all, it concerns new technologies that accompany us in all areas of our lives and activities - information and communication technologies (ICTs) - and also directly affect not only our present, but also the future" [16].

In recent years, the use of cloud-based modeling and technology and service-oriented architecture has been increasingly widespread in the world, offering greater use of modeling and simulation (M&S) capabilities to meet critical societal needs [17].

Modeling and simulation is the use of models (such as a physical, mathematical or logical representation of a system, entity, phenomenon, or process) as a basis for modeling to analyze data used to make managerial or technical decisions. In a computer application, M&S is used to build a mathematical model that contains the key parameters of a physical or societal model. The mathematical model represents the physical model in virtual form and the conditions that set up an interesting experiment are applied. Mathematics as a general language to describe the Universe provides learners with understanding in what way the world is united. Simulation means that the computer calculates the results of these conditions on a mathematical model - and outputs the results in a format that is read by machine or person, depending on the implementation. Simulation is increasingly used in the sense of "simulation". To some extent, it is "game", a cognitive task that can be a part of the general education process [18].

M&S as a Service (MSaaS) is a new concept that includes a focus on servicing and delivering M&S applications through a cloud computing model as a service to provide more simulation environments that can be deployed and executed at the user's request. The MSaaS paradigm supports offline use as well as the integration of multiple simulated and real systems into a single cloud simulation environment when needed.

The MSaaS concept has to be tested at the national level in different educational scientific and practical structures in various experiments. As it was noted, the results of the experiments and the initial operational programs in military area (including training and practical use) demonstrated that "MSaaS was capable of realizing that products, data and processes are conveniently accessible to a large number of users when and where required" [17, p. 21]. As researcher highlighted, "M&S products are highly valuable resources and it is essential that M&S products, data and processes

are conveniently accessible to a large number of users as often as possible. However, achieving interoperability between simulation systems and ensuring credibility of results currently requires large efforts with regards to time, personnel and budget” [17, p. 15].

For educational tasks, this concept can become one of the main areas in students' cognitive activity, provided that the methodological, technical, organizational and content issues are reasonably developed.

M&S as a Service (MSaaS) can be realized as both the national and an educational institution level approach for discovery, composition, execution and management of M&S services.

Realization of this concept needs to solve three groups of problems: the MSaaS Operational Concept, the MSaaS Technical Reference Architecture, and the MSaaS Governance Policies.

The general architecture of the learning process with MSaaS can be represented as the administration of the M&S cloud(s) exchanging by metadata with customers (teacher and students) of the education institution (Fig.2).

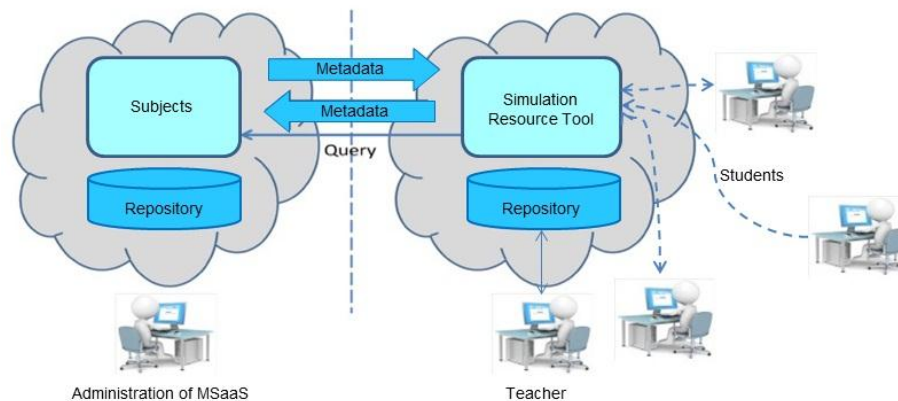


Fig. 2. Example of the administration of the M&S clouds exchanging by metadata

Repository on the administration side contains all available modeling areas that can be specified and adjusted to the needs of the particular education institution and/or subject area.

These results correspond the current needs to change digital transformation of education to prepare professionals for new and future jobs such as big-data, data scientist, data analytics etc.

3.1 Simulation as a tool to create new knowledge on the base of collected data and data mining for science and edu

The Education Community Framework for M&S as a Service enables:

- The community of users to discover new opportunities to teach/learn/train and to work together.
- Users to enhance their operational performance and optimizing effort in the process.
- M&S aims to provide the user with discoverable services that are readily available on-demand and deliver a choice of applications in a flexible and adaptive manner.

The MSaaS concept is illustrated in Figure 3. MSaaS is an enterprise-level approach for discovery, composition, execution and management of M&S services. MSaaS provides the linking element between M&S services that are provided by a community of stakeholders and the users that are actually utilizing these capabilities for their individual and organizational needs.

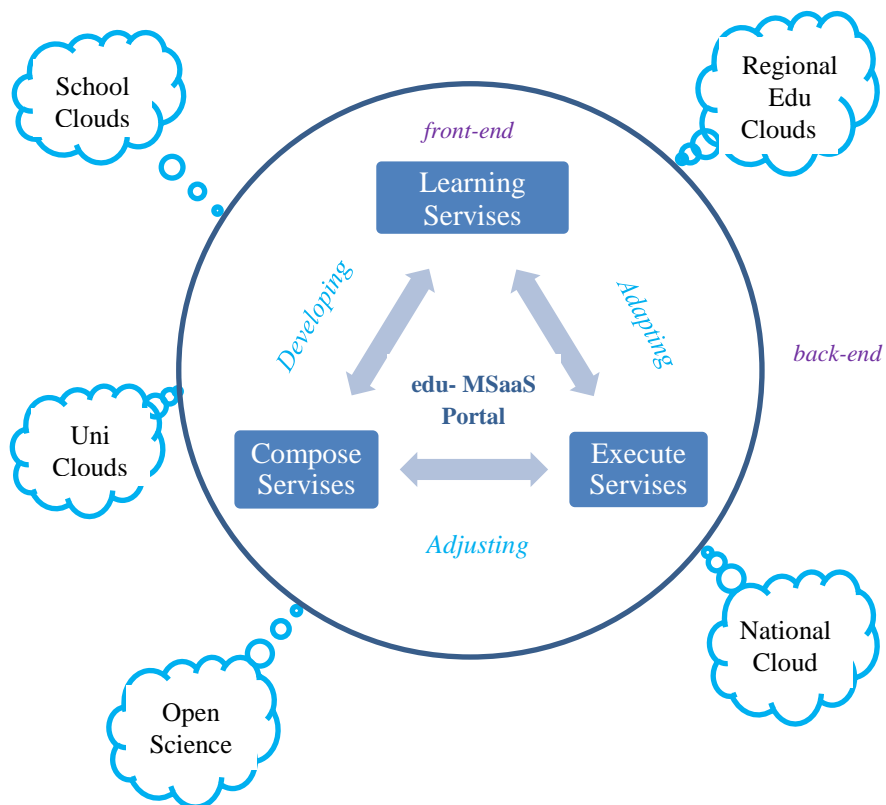


Fig. 3. The edu-MSaaS concept

Using proposals of authors for M&S Service in military field [19], application to the Education Community Framework for MSaaS defines user-facing capabilities (front-end) and underlying technical infrastructure (back-end), as it is shown in Fig.3 with development and adaptation to the specific type of activity as the education. The front-end can be called the edu-MSaaS Portal. It provides access to a large variety of M&S capabilities from which the users are able to select the services that best suit their requirements, and track the experiences and lessons learned of users. The users can discover, compose and execute M&S services through the front-end, which is the central access point that guides them through the process:

Discover Services (a mechanism for users to search and discover M&S services and assets: data, knowledge, services, models, and scenarios):

- Specify and discover scenario.
- Define simulation requirements and discover services.
- Define types and levels of game-based learning.

Compose Services (The ability to compose discovered services to perform a given simulation use case. It is envisaged that simulation services will be composed through existing simulation architectures and protocols and can be readily executed on-demand. Simulation technology will enabling further automation of discovery, composition and execution):

- Design simulation environment.
- Compose services.

Execute Services (The ability to deploy the composed services automatically on a cloud-based or local computing infrastructure):

- Deploy and execute a composition of services.
- Collect and analyze data.
- Save simulation environment for reuse.
- Provide cybersecurity support for users.

A further description of the process and associated activities prescribed for a user is assumed that the following supporting services and infrastructure are available:

- Availability of a registry with information about available M&S services and capabilities.
- Availability of a repository with access to the actual M&S services and capabilities.
- Availability of an MSaaS Portal as a central Front-end providing discovery, composition and execution services.
- Availability of networking and hardware infrastructure (Cloud provider, local hardware, network) on which to execute the simulation services.

Such proposals can be especially useful if expanding M&S service to AR/VR environment [20], lifelong learning paradigm [21] as well as trends and opportunities of learning in social networks [22].

4 Concluding Remarks and Future Work

The model proposed allows representing ITC evolution from viewpoint of the ratio of the number of devices and served users. The current stage of such an evolution is considered as wearable and modeling one, flexible and person-oriented. Special attention is paid to modeling and simulation (M&S) as an important trend in education/training for the business and industry. The new approach in its use in context of cloud-based technologies is proposed: Modeling and Simulation as a Service (MSaaS). The general architecture is proposed for consideration.

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Cloud Resources and Services for Development of Self-Educational Competence of Future IT Specialists: Business Process Modelling and Examples of Using

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Abstract. The research is devoted to the scientific substantiation of building self-educational competence of future IT specialists using the cloud resources and services by applying the process approach. The application of the process approach to management and educational activities in higher education institutions, the structure of self-educational competence and the use cloud resources and services. Taking into account the requirements of the modern labor market, the specifics of training future IT specialists and the need to build their own self-educational competence, the structured analysis and design techniques model of self-educational competence of future IT specialists was developed. This model identifies the following processes: elaboration of the e-learning course (ELC) with integrated cloud resources and services for online learning, organization of the training activities in line with the mixed learning technology, organization of students' project activities, assessment of the level of development of the professional and self-educational competences of future IT specialists. Input and output data, managerial impacts and mechanisms, and resources for the implementation of the process are determined for each of the processes. The influence of the implementation of each process on the development of components of self-educational competence is substantiated. The level of self-education competence of future IT specialists is determined based on the proposed indicators. The results of the study confirm the effectiveness of the implementation of the proposed model of the system of development of self-educational competence in the future specialists in information technologies using the cloud resources and services.

Keywords: Cloud Resources, Cloud Services, Business Process Modelling, Self-educational Competence, Future IT Specialists.

1 Introduction

The modern stage of development of higher education is connected with the transition to the practical realization of a new educational paradigm aimed at creating a holistic system of continuous education and expanding the sphere of students' self-education under the conditions of active use of information and communication technologies (ICTs) [1], which make it possible to build and develop self-educational competence, self-organization skills and self-education of future specialists. It is not sufficient to build professional, research or communicative competences to train a highly skilled information technology specialist who is ready for professional activity under the conditions of the rapid development of the IT industry. The successful professional development of a future IT specialist requires the development of a self-educational competence as a basis for further self-improvement and competitiveness in the labor market in the context of intensive development of information technologies, which covers a wide range of cloud resources and services for the development of self-educational competences in the process of training future IT specialists.

The effectiveness of the self-educational competence development in IT students in the context of widespread use of information technologies, in particular, the cloud-based learning environment, mass open online courses (MOOCs), cloud resources and services for practical work, technology platforms, services for teamwork, etc. also depends on learning technologies. The application of blended, adaptive, and project-based learning technologies contributes to a qualitative development of professional and self-educational competences. In this regard, the development of a modern model for the development of professional and self-educational competences of future IT professionals capable of solving complex, practical-oriented tasks are necessary and relevant.

The purpose of the article is to identify and model business processes for learning using cloud services to develop self-educational competence for IT students.

2 Theoretical Background

The essence of the process approach in the management of the educational institution is that the emphasis in task setting and performance evaluation is transferred from the functional units and quality elements to business processes, that is, processes that create values for the consumer and educational institution [2]. The process approach in education is meant to regulate the educational process on the basis of assessing its condition according to specially defined quality criteria for all the components of the process itself, as well as the factors that influence the final result [3]. A. Graule, V. Azarov, M. Mizginova touch upon issues concerning process-service approach to e-learning design and business processes management [4].

Based on the analysis of theoretical and methodological principles of self-educational competence development in higher education, the content essence, the structure of self-educational competence of future IT specialists as a set of motivational-value, organizational-technological, practical-activity, reflexive-analytic components and the level of its development are determined [5], [6], [7]. The content of the notion of „self-

educational competence of future IT specialists” will be understood as the confirmed ability of the individual to carry out self-educational activities to deepen the theoretical knowledge and improve practical skills in order to respond flexibly to the rapid changes in the modern information society and the ability to independently solve the professionally-orientated problems in the field of information technology with the aim of increasing the personal level of competitiveness in the labor market [7].

3 The Presentation of the Main Research and Explanation of Scientific Results

The questions and problems concerning the quality of educational services, training of specialists in conformity with modern requirements of the labor market and the availability of the necessary knowledge, skills and abilities are a priority task of the sphere of education. The quality of specialist training depends to a certain extent on the organization of the educational process, the competence of the academic staff of the institution of higher education (HEI), as well as on information and methodological support. The research of the process approach problems in the educational process, as well as the model of development of professional and self-educational competence of IT specialists, is presented in scientific works, however, there is a need to study complex issues of managing the process of self-educational competence development and implementation of its strategic planning.

3.1 Process Approach Model of the Self-Educational Competence

Improving the quality of training and development of self-educational competence of IT students is one of the main requirements at present, especially on the IT labor market. A process approach was chosen to build a model of the self-educational competence of future IT specialists. The process model of forming the self-educational competence of future IT specialists is considered as successive parallel sub processes of competences development within the organization of various stages of the educational process and the application of various teaching technologies.

Given the rapid changes in the modern information society and the need to continuously increase IT specialists’ level of competitiveness in the labor market, it is necessary to determine the conditions under which the ability of future IT specialists for self-improvement and professional growth will be most effective.

The main advantages of the process approach while training IT students are the following:

- coordination of various process groups of the organization of students’ educational and project activities;
- improvement of the effectiveness and efficiency of the organization of the educational process;
- result-orientated process, which means the commitment to the increase of the students’ professional and self-educational competences level;

- increase in the predictability of the results;
- identification of opportunities for purposeful improvement of processes.

Principles of the process approach are the manifestation of flexibility and continuous control, when all the activities of the enterprise are considered as a network of interconnected and interrelated business processes and their subsequent management in accordance with the PDCA cycle (Plan-Do-Check-Act). In the standards of ISO 9000 series, the PDCA cycle is described as follows [8]:

- Plan: process planning (accounting for input data that initiate the process; operational definition of decomposed goals and tasks for executors based on the objectives of the process; operational distribution of responsibilities and powers; definition of „control points” for ongoing verification; risk assessment for the quality of the process; determination of indicators, criteria and methods for evaluating and monitoring the effectiveness of the process, others);
- Do: execution of the process (an algorithm for implementing all stages and operations with the detail and form determined for the required process, measures to ensure the stability of the process and compliance with the scheduled parameters, guidance on the application of necessary documents, records, etc.);
- Check: evaluation and analysis of the effectiveness of the process (description of the actions for data registration according to the determined parameters of the process effectiveness, comparison with established criteria, trends identification, identification of inconsistencies that occurred, as well as potential inconsistencies, the development of reporting protocols, etc.);
- Act: initiating and implementing actions to improve and enhance the process (description of actions with analysis of causes of non-conformities, development and implementation of corrective and/or various precautionary measures).

The inputs and outputs of processes, their sequence and interaction can be described by a process model, which reflects all activities of the organization of the educational process at the HEL. Under the process, we will understand the totality of interconnected and interacting activities aimed at converting inputs into outputs. The scheme of the process approach implementation is presented in fig. 1.

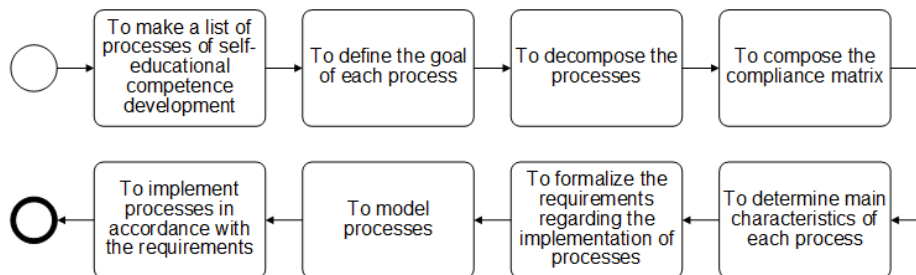


Fig. 1. The scheme of implementing the process approach to the development of self-educational competence

To reach the set goals, a model of the process of the development of future IT specialists' self-educational competence using cloud resource and services was developed, which is graphically presented in fig. 2.

The model construction of the process of the self-educational competence development involves preliminary selection of its main groups of processes, namely: the preparation of ELCs containing integrated cloud-based academic resources and services (1), the organization of student learning activities based on blended and flipped learning technologies (2) and project activities of students using the services for team management (3), the definition and analysis of the levels of development of professional and self-educational competence of future IT specialists (4).

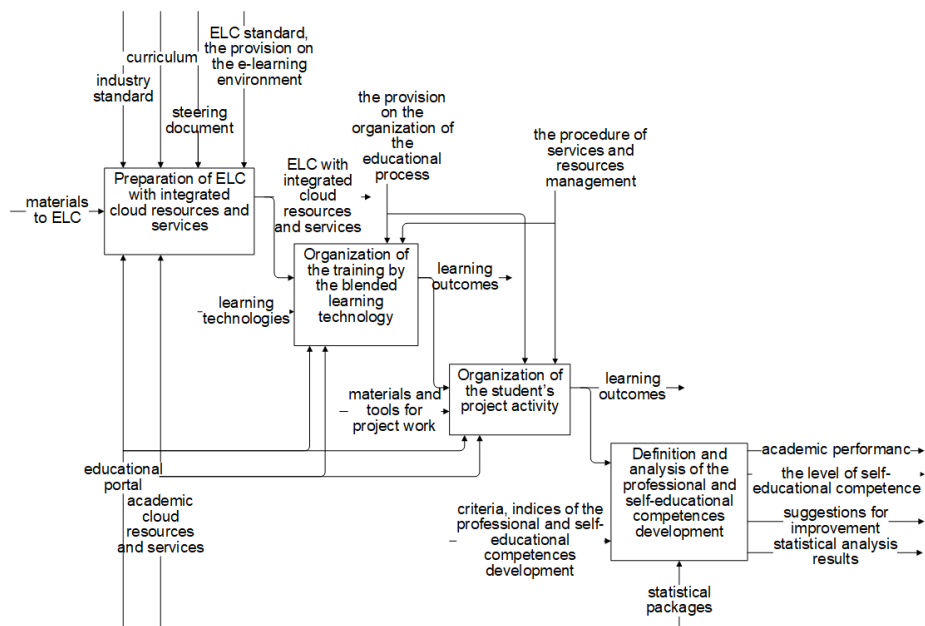


Fig. 2. Decomposition of the context diagram in the IDEF0 standard (SADT methodology)

3.2 Process 1. Integration of Cloud-Based Academic Resources and Services into ELC

The purpose of the process is to develop an ELC with integrated cloud resources and services for the professionally-oriented academic disciplines.

The regulatory framework, based on which future IT specialists are trained, can be subdivided into relevant industry standards, approved in the subject area 12 „Information Technologies”, corresponding curricula for training future IT specialists and steering documents for academic disciplines according to the curriculum. These normative documents determine the preconditions for access to learning, the orientation and main focus of the program, the amount of ECTS credits necessary for obtaining a bachelor's or master's degree, a list of general and special (professional) competences,

normative and optional content of specialist training, formulated in terms of learning outcomes and requirements for quality control of higher education.

With the fast-growing Massive Open Online Courses (MOOC) community and the increase in the number of Learning Management Systems (LMSs) available online, the amount of shared information is massive. Current LMS – in particular, MOOC providers – offer many advanced content delivery techniques: interactive video, active retrieval practices, and quizzes to enhance the pedagogical process [9]. The success of MOOCs (Massive Open Online Courses) is not limited only to their openness to all heterogeneous learners, but also in their integration into the curricula of initial training in higher educational institutions [10]. MOOCs support many forms of instruction, including video lectures, reading with conceptual questions, discussion boards, and various forms of learning-by-doing with automated or peer feedback [11].

The model of system S can be presented as a set of values, which describe the process of its functioning and in the general case form such subsets:

- the totality of input data of the system: $x_i \in X, i = \overline{1, n_X}$;
- the totality of mechanisms and tools impact on the system: $m_k \in M, k = \overline{1, n_M}$;
- the totality of managerial impact on the system: $u_j \in U, j = \overline{1, n_U}$.

Herewith, in the listed subsets we distinguish controllable and uncontrollable variables. In the general case X_i, M_k, U_j are the elements of non-intersecting subsets containing both deterministic and stochastic components. In modeling system S , input data, mechanisms and tools impact and managerial impact on the system are independent (exogenous) variables, which in vector form are, respectively, presented as follows:

$$Y_{ni}(t) = A_n(x_{n1}, \dots, x_{ni}, m_{n1}, \dots, m_{nk}, u_{n1}, \dots, u_{nj}), \text{ where } t - \text{time.}$$

Input data: X_I – materials for ELC, where $X_{I,1}$ – a list of competences to be formed in the students within the academic discipline; $X_{I,2}$ – academic resources and services; $X_{I,3}$ – criteria for selecting academic resources and services; $X_{I,4}$ – theoretical course materials; $X_{I,5}$ – course lab sessions; $X_{I,6}$ – assignments for independent work; $X_{I,7}$ – consolidating assignments of the course.

Management: $M_{I,1}$ – industry standard; $M_{I,2}$ – curriculum; $M_{I,3}$ – steering documents; $M_{I,4}$ – ELC structure standard; $M_{I,5}$ – the provision on the e-learning environment.

Mechanisms and tools: $U_{I,1}$ – CLMS; $U_{I,2}$ – cloud resources; $U_{I,3}$ – cloud services.

Decomposition of A_I process: $A_{I,1}$ – analysis and selection of cloud resources, services; $A_{I,2}$ – supplementing the theoretical material and tasks for the independent work with ELC cloud academic resources; $A_{I,3}$ – arranging lab sessions and consolidation classes with the use of selected cloud services.

Output data: V_I – ELC with integrated services and resources, where $V_{I,1}$ – theoretical materials of ELC with integrated cloud services and resources; $V_{I,2}$ – lab sessions with integrated cloud services; $V_{I,3}$ – tasks for the independent work with integrated cloud resources and services; $V_{I,4}$ – consolidation classes with integrated cloud services.

For the description of the process execution scenario, a Business Process Modelling Notation (BPMN) was selected. The sequence and logic of the actions performed by the participants of the process of integration of cloud resources and services in the ELC is demonstrated in fig. 3.

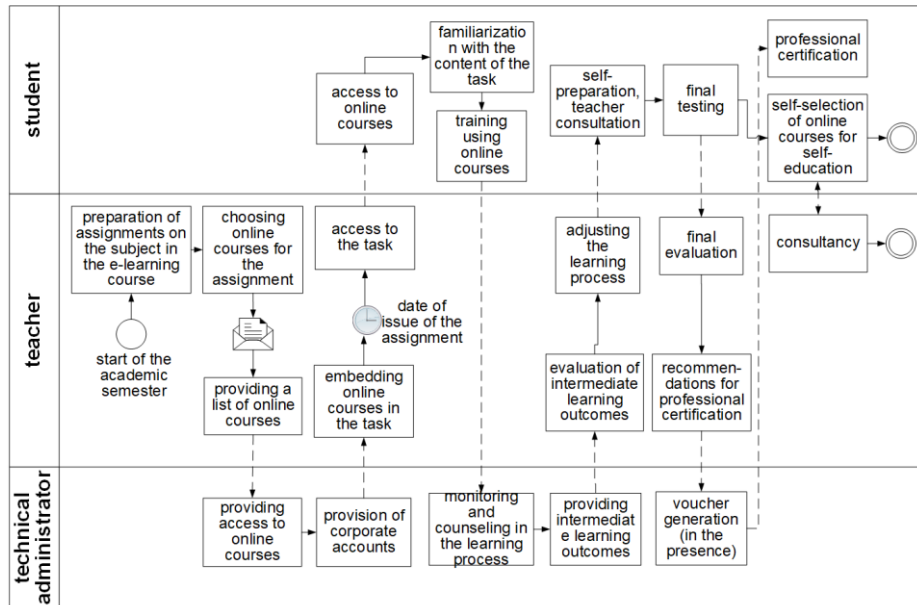


Fig. 3. BPMN for process of the integration cloud-based academic resources and services into ELC

Preparation of ELC resources containing integrated cloud resources and services will expand the opportunities for students to independently study the learning materials developed by leading technology companies. Such resources are constantly updated in line with changes in technology, which gives an opportunity to get the latest materials for self-education. This creates a pool of resources and services within one ELC to study one discipline. When mastering the educational material, performing practical tasks, reflecting on the use of these resources and services, students understand the need for self-education, which motivates them to master the new material.

For training IT specialists, it is advisable to use the academic resources of leading IT companies such as Microsoft Imagine Academy, Microsoft Virtual Academy, Cisco Networking Academy, IBM Academic Initiative, and various online technology platforms (MOOCs) such as Khan Academy, edX, Coursera, Prometheus et al. This allows students to complete their studies under „computer science” with the subsequent award of the corresponding certificate. This will allow them to obtain the necessary knowledge in the field of information technology, which they can easily apply in practice during their professional activities in the future. An example of tasks for independent work with integration course „BPMN 2.0 with Brian: A Beginner’s Guide” Udemy is shown in fig. 4.

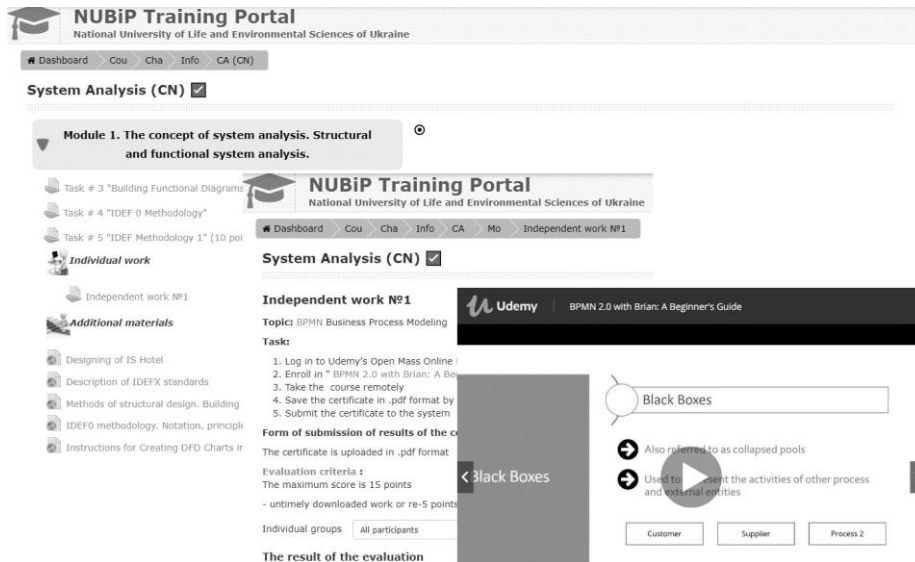


Fig. 4. A sample task with integrated resource massive online courses Udemu

For setting practical tasks, laboratory and group activities, such cloud services should be selected for project work on the task: platforms, software, software environments.

3.3 Process 2. Blended Learning Using Integrated Cloud Resources And Services into ELC

The purpose of the process is to effectively organize student learning activities in studying theoretical material and acquiring practical skills and abilities.

Organizational flipped classroom where students view screencasts, read textbook material and take an on-line quiz before class has been implemented in a process dynamics and control course. The class periods involve brief lectures summarizing what they have learned, and include discussions and advanced problem solving using MATLAB [12]. Examples of the implementation of flipped learning in the Ukrainian and Polish Universities in the process of teaching disciplines of the Information Technology cycle or during introduction to the module „Information technology” are presented in the following works [13]. Blended learning technology integrates the traditional learning tools with the tools of new information technologies [14]. Integrating the information and methodological support with the blended learning technologies is pedagogically appropriate and encourages optimizing the learning process and its computerization [15].

For organizing blended and flipped learning in order to form self-educational competence, we should develop a program of blending different types of student activity in accordance with the stated tasks: online training, individual, group training under the guidance of a teacher, cooperative learning.

Input data: X_2 – learning technologies, where $X_{2,1}$ – educational materials and activities of the ELC; $X_{2,2}$ – a blended learning program; $X_{2,3}$ – a flipped learning program; $X_{2,4}$ – assessment criteria (scale).

Management: $M_{1,1}$ – the provision on the organization of the educational process; $M_{1,2}$ – services and resources management procedure.

Mechanisms and tools: $U_{1,1}$ – CLMS; $U_{1,2}$ – cloud resources; $U_{1,3}$ – cloud services.

Decomposition of A_2 process: $A_{2,1}$ – organization of blended learning; $A_{2,2}$ – organization of flipped learning; $A_{2,3}$ – assessment and analysis of learning outcomes.

Output data: Y_1 – learning outcomes, where $Y_{2,1}$ – completed tasks for lab sessions; $Y_{2,2}$ – certificates of using cloud resources; $Y_{2,3}$ – completed tasks for independent work; $Y_{2,4}$ – control assessment (score); $Y_{2,5}$ – results of students' reflection.

Teachers, students and technical administrators are participants in this process. A model of the process of blended learning using integrated cloud resources and services in the ELC is presented in fig. 5.

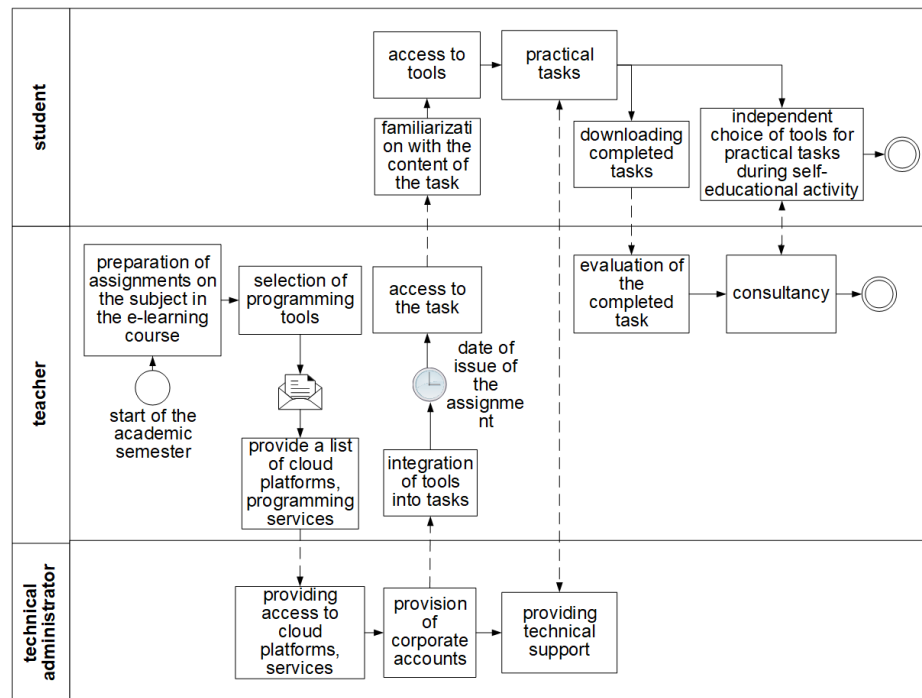


Fig. 5. BPMN for blended learning process with using integrated cloud resources and services in the ELC

An example of organizing learning activities for student blended learning technology using cloud platform Microsoft Azure is shown in fig. 6.

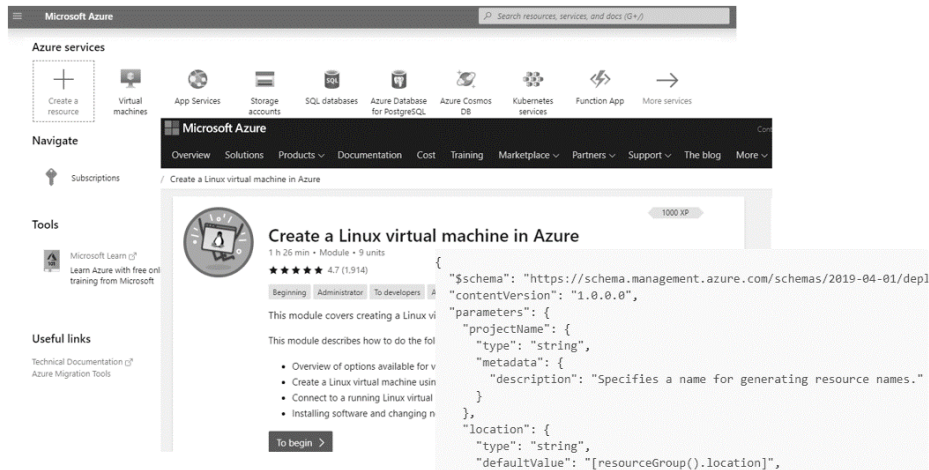


Fig. 6. Example of using the cloud platform Microsoft Azure

As a result of this process, students improve the skills of an independent organization of study material, completion of practical tasks with the aid of recommended resources and services, develop soft skills, aimed at the proper time management of completing tasks, the organization of communication with the teacher and students, the organization of personal learning environment, information management and personal knowledge.

3.4 Process 3. Students' Project Activities Using the Services for Team Management

The purpose of the process is to organize professionally-oriented team projects, which will increase students' motivation for self-education and promote the development of both professional and personal skills.

As one of the general competences of future IT specialists is the ability to work in a team, it is recommended to use the project methodology while training future IT specialists. Various task and project management software tools are employed to support team collaboration, for example, tools for knowledge management, information exchange, communication, shared authoring and collaborative work [16]. The use of SharePoint for designing an e-environment for the project implementation in the field of study contributes to the students' motivation to learn and develop both hard skills and soft skills [17], [18], [19].

Teamwork on project implementation is quite effective and productive, as it allows solving complex and cumbersome tasks that cannot be performed on time and effectively alone, even by highly skilled professionals.

Input data: X_3 – materials for the project activity, where $X_{3,1}$ – tasks; $X_{3,2}$ – performance plan; $X_{3,3}$ – services for team work; $X_{3,4}$ – services selection criteria; $X_{3,5}$ – comments in the process; $X_{3,6}$ – assessment criteria.

Management: $M_{1,1}$ – the provision on the organization of the educational process; $M_{1,2}$ – services and resources management procedure.

Mechanisms and tools: $U_{1,1}$ – CLMS; $U_{1,2}$ – cloud resources; $U_{1,3}$ – cloud services.

Decomposition of A_3 process: $A_{3,1}$ – task setting, selection of the service for team work; $A_{3,2}$ – monitoring of the project implementation; $A_{3,3}$ – results presentation; $A_{3,4}$ – results assessment.

Output data: Y_I – learning outcomes, where $Y_{3,1}$ – completed project; $Y_{3,2}$ – mark (score); $Y_{3,3}$ – reflection results.

Business process model of the students' project activities using the services for team management is shown in fig. 7.

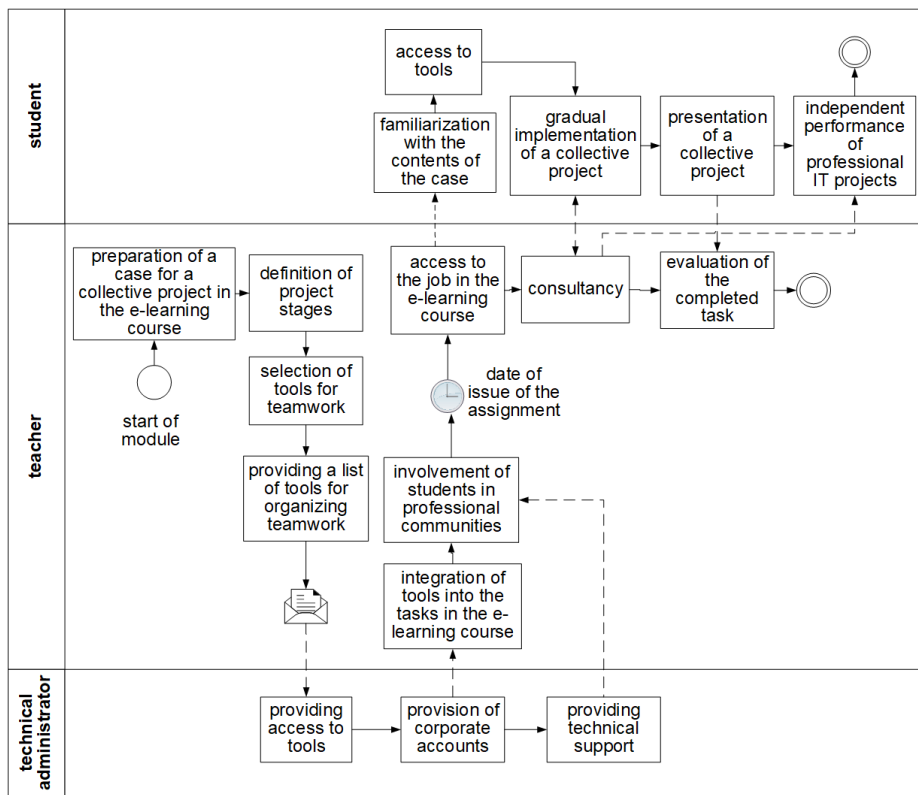


Fig. 7. BPMN for process of the students' project activities using the services for team management

This process makes it possible to form in the students not only a professional integral competence, as in the process of project work a complex systemic problem is solved, which involves the professional competences formed as a result of studying various disciplines. The need to carry out part of the project independently and in collaboration develops students' self-educational competence and a set of cognitive, com-

municative and organizational soft skills. An example of organizing a team of professional projects using a cloud service to manage the Microsoft Teams team is shown in fig. 8.

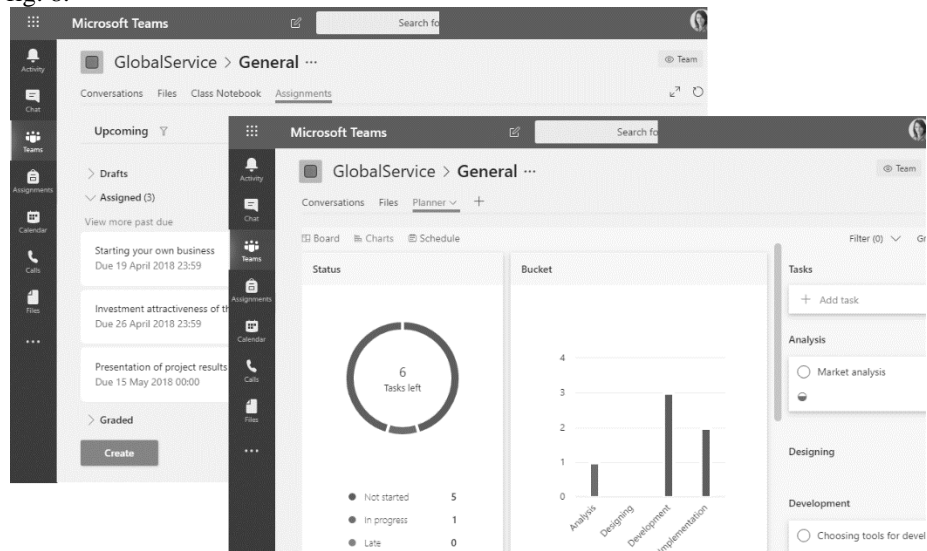


Fig. 8. Example of cloud service Microsoft Teams in the group project work

3.5 Process 4. The Definition and Analysis of the Levels of Development of Professional and Self-Educational Competence of Future IT Specialists

The purpose of the process is to analyze the effectiveness of using cloud-based academic resources and services for the development of self-educational competence.

The level of development of professional competence is determined using competently oriented tasks and surveys – in accordance with the requirements of the industry standard. The level of self-educational competence is determined on the basis of indicators (indices), which are determined in accordance with the component structure of self-educational competence [7].

Input data: X_4 – levels of professional and self-educational competence, where $X_{4,1}$ – the mark for the educational activity; $X_{4,2}$ – the mark for the project activity; $X_{4,3}$ – reflection results; $X_{4,4}$ – indicators (indices) of self-educational competence development; $X_{4,5}$ – statistical analysis methods.

Management: $M_{1,1}$ – the provision on the organization of the educational process.

Mechanisms and tools: $U_{1,1}$ – statistical packages.

Decomposition of A_4 process: $A_{4,1}$ – defining the assessment criteria; $A_{4,2}$ – defining the criteria and indices of the professional and self-educational competences development; $A_{4,3}$ – assessment of academic performance; $A_{4,4}$ – defining the level of self-educational competence.

Output data: $V_{4,1}$ – academic performance, where $V_{4,2}$ – the level of self-educational competence; $V_{4,3}$ – results of statistical analysis (absolute academic performance, quality, progress in the development of professional and self-educational competence); $V_{4,4}$

– suggestions on the improvement of the processes of self-educational competence development.

In order to improve the process of self-educational competence development, it is necessary to obtain the results of its development according to different indicators and to make a decision on changing the forms, methods and tools for forming the corresponding components.

4 Results of Research

Experimental verification of the effectiveness of the educational process organization in accordance with the developed model was carried out taking into account the processes decomposition and the following functions: integration of Microsoft Imagine Academy, Cisco Networking Academy, IBM Academic Initiative, Prometheus academic resources into ELC; the use of cloud services and resources for laboratory classes, tests and practical tasks: programming environments, database management, virtual simulation laboratories, data processing and analysis platforms, and more; the use of cloud services and resources for the organization of the project work: Microsoft Office 365, G Suite, Jira etc.

The level of self-educational competence development of the IT-faculty students was assessed by the following indicators:

- motivation to mastering new educational materials; the ability to make an independent choice of online resources to continue their own self-development in the chosen direction; to build and adjust their own self-learning trajectory by regulating and controlling the time of training in additional online courses; to form an adequate self-assessment of their achievements; the ability to pass professional certification;
- ability to independently choose the best way to achieve the goal, to determine the sequence and duration of its stages, to select the tools and services to complete the task;
- ability to search, analyze and collect the necessary information, plan activities, establish communication and team collaboration, facilitate the increase in students' motivation for self-education, development of both professional and personal skills.

The characteristics of the levels are developed for each indicator: low, middle, high [7]. Research methods for each process include observation, testing, diagnostics of levels of self-education competence development, evaluation of laboratory and independent work, monitoring of the development of self-education and professional competence, evaluation of educational projects, questionnaires, reflection.

The control group adhered to traditional teaching technologies without the use of cloud services and resources.

For statistical verification of the obtained results, the null hypothesis is formulated: the use of cloud resources and services does not affect the level of self-educational competence of future IT specialists. That is, the existing changes in the levels of self-education competence are random. Frequency tables (conjunction tables), criterion χ^2 and one-way ANOVA were used for this purpose. The calculated Pearson criterion

value (for significance level 0.05 and 6 degrees of freedom) is greater than the critical value: $40.021 > 12.592$. Therefore, we accept the alternative hypothesis: the use of cloud resources and services influences the level of self-education competence of students of IT profession.

The comparison of the level of self-educational competence in experimental and control group of students regarding the implementation of the process approach is presented below (fig. 9).

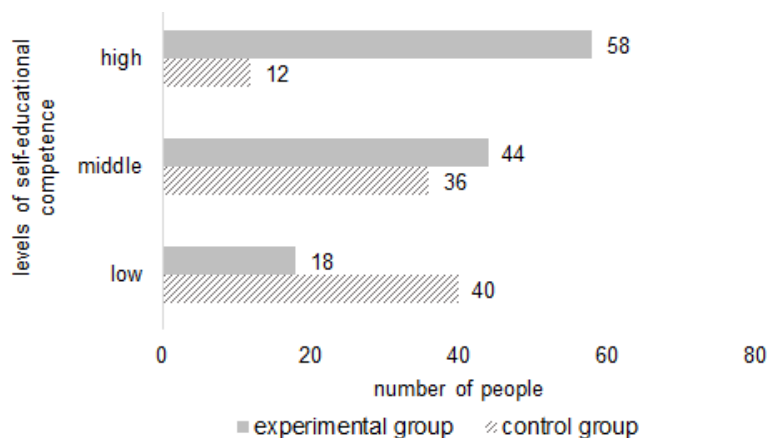


Fig. 9. The comparison of the level of self-educational competence development in experimental and control groups (the total number of participants in the experiment is 208 people)

Thus, the level of development of self-educational competence in the control and experimental groups differs. We see that the number of students with high levels of self-education has increased by 34%. The number of students with an average level of self-education competence decreased by 4%, with a low level - by 30%.

Evaluation of results of the presented model of the process approach to the development of self-educational competence of future IT specialists using the cloud services and resources proved the expediency of its application, as evidenced by the results of diagnosing the levels of self-educational competence of future IT specialists.

5 Conclusions

The process approach to the self-educational competence development in the future IT specialists makes it possible to clearly identify the interrelations between processes and the necessary resources to ensure their implementation. This approach contributes to improving the organization of the educational process with the aim of increasing students' level of competence by activating integrated team training, organizing project activities, developing students' motivation to self-education, which ultimately results in an increase in the level of students' progress in professionally-oriented academic

disciplines as well as in a more effective use of cloud resources and services. The decomposition of the processes of self-educational competence development of the future IT specialists enables the academic staff to obtain an integrated technology for the implementation and monitoring of the increase in the level of the development of students' self-educational competence.

Further research may focus on developing resources for students to work independently in accordance with their dominant teaching styles and researching new factors that influence the development of self-educational competence of future IT professionals.

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Research on Metacognitive Skills of Software Testers: a Problem Statement

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Abstract. The article raises the problem of researching the metacognitive skills of software testers in modern IT companies. It figures out what are the specific features of software testing experts' activity and what soft skills (non-technical skills) are the leading ones for its implementation, as well as what is the place among them for metacognitive skills. Using a survey among professionals in the field of software testing, the article establishes a connection between the professional title of software testing professionals achieved and the level of their metacognitive skills.

Keywords: software testing specialist, soft skills, metacognitive skills, training

1 Introduction

The mass introduction of digital technologies into the life of modern man has greatly shifted the accents and vector of IT development. The main vector in software development has shifted from manufacturability and innovativeness to its convenience, stability, reliability, and most importantly, quality: the Internet banking user would prefer the absence of calculation errors in finances to the color of the interface, and the user of medical software the accuracy of medical evidence to the speed they get it. Emphasis on software quality led to the emergence of a separate specialization of IT professionals, whose main purpose is to directly control the compliance of the developed product with the expectations of users and customers. Software testing is the process of analyzing and operating software to identify differences in existing and required operating conditions (defects) and to evaluate the features of this software (ANSI/IEEE 1059, 1994).

To date, testing has evolved into an independent industry of information technology with its unique techniques and theoretical framework. Demand for relevant professionals has grown significantly over the past 10 years. In many companies most of the time developers used to test their product for efficiency themselves, whereas in today's realities special departments and test teams are created, and they have their internal hierarchy and subordination.

Therefore, taking into account the growth of the IT industry in general and a particular focus on quality issues, training software testers is an urgent task for the modern IT sphere.

The analysis of domestic and foreign experience in preparing students of IT-specialties shows that theoretical and practical content of education was created based on the general concept of "information technology worker" or "software engineer", without paying attention to specific specializations (Classification of professions DK 003:2010). To date, Ukrainian higher education institutions do not single out testing as an independent specialty, and that requires a specific approach to training future professionals.

The analysis of specialized publications (Raluca Florea, Viktoria Stray, 2018) and current vacancies for the position of testing specialist shows that any tester must have basic knowledge of architecture, development and application administration and popular operating systems. In addition, the specialist must have a basic understanding of programming languages, be able to read code intuitively, as well as quickly adapt to new technological tools and environments. Software testing also has its theoretical framework, which includes a set of basic techniques and approaches to writing tests, passing them, analyzing results and potential vulnerabilities of the product. Moreover, the tester should apply in practice popular approaches to test documentation and reporting.

However, rather moderate requirements from employers for the quality of technical training of software testing specialists are offset by the extremely high requirements for their non-technical skills. Unimpeded communication with any team member, direct communication with the customer, active participation in planning and direct influence on the development process - all these tasks of professional activity require non-technical skills of the specialist, and they should be formed at the stage of his professional training in the institution of higher education.

In basic documents of EU member countries (The European Qualifications Framework, European Skills, Competences, Qualifications and Occupations, 2019;), as well as the United States (IFTF, AI Forces Shaping Work and Learning in 2030, 2018), such non-technical non-professional skills are called 'essential skills' or 'soft skills'. These documents make it possible to introduce a common understanding and a unified classification of soft skills for the global economic space.

To date, soft skills are defined by a set of non-specialized, super-professional characteristics, which are responsible for professional success, high productivity and, unlike specialized (technical) skills, are not related to a specific field of application. To the category of 'soft skills' researchers include:

- individual qualities and attributes of a person (Cobb, 2015; Goleman, 2000; Yarkova, Cherkasova, 2016), such as self-organization, the ability to speak in public;
- interpersonal communication skills (Robles, 2012) or teamwork, collaboration and joint effort in a project office (Grugulis, Vincent, 2009; Yarkova, Cherkasova, 2016);

- skills focused on human relationships, as well as characteristics that form emotional intelligence, that is the ability of a person to solve behavioral and cognitive tasks (Peterson, Van Fleet, 2004);
- cognitive and methodological skills (Cinque, 2016) that are responsible for successful problem solving and manifested in complex ways of thinking, the ability to evaluate and use knowledge and information (Matteson, 2016); critical thinking (IFTF, AI Forces Shaping Work and Learning in 2030, 2018); the ability to creatively solve complex problematic tasks; the ability to make quick decisions under time pressure (Yarkova, Cherkasova, 2016; IFTF, AI Forces Shaping Work and Learning in 2030, 2018).

The latter group of soft skills includes metacognitive skills or metacompetences, that is the capacity to work on competencies, to reframe and transfer them from one field to another, even from informal to formal learning (Cinque, 2016). It is stated there (Haselberger, Oberhuemer and other authors, 2016) that soft skills represent a dynamic combination of cognitive and metacognitive skills, interpersonal, intellectual and practical skills.

Metacognitive skills of a specialist are workaround techniques of metacognitive regulation of his professional activity and, based on activity and metacognitive approach (Karpov, Cholodna), they contain:

- goal-setting ability (formulation of objectives, conversion of objectives into tasks, result objectification, defining criteria and indicators of the result, to divide the problematic situation into known and unknown);
- the ability of anticipation (predicting scenarios of problematic situations, ways of solving a problem, as well as ways of conditions development, identifying probable risks, creating thinking models);
- decision-making skills (formulation of hypotheses, alternatives, choosing a method of decision-making, analyzing the type and kinds of decision-making, working with errors and outcomes of decision-making);
- planning ability (developing a work plan, correlating the work plan with the purpose and the model);
- reflexive or metacognitive self-control skills (analyzing the result of the activity, applying the mechanisms of reflection, determining the ways of correcting the activity, slowing down and termination of the activity, conducting a comprehensive reflective analysis of individual activity).

Among the competences of IT professionals related to the metacognitive group of soft skills the most important are: the ability to work with complex problems in conditions of uncertainty and ambiguity, the ability to plan their activities and adjust their course (Software Engineering Body of Knowledge); ability to see the task simultaneously at different levels of detail, the ability to formulate requirements and evaluate opportunities, the ability to make decisions in the limited time, strategic thinking, the ability to analyze their own mistakes, etc. (Shchedrolov, 2011); ability to organize their activities and effectively manage time, the ability to take into account the influence

of environmental factors on the performance of their professional activity (Kruglik, 2017).

It is metacognitive skills that enable the monitoring and management of the specialist's cognitive, emotional and regulatory processes that ensure the effectiveness of his work (Karpov, 2014).

And whereas the problem of the development of software engineers' communicative skills in the process of professional training and software testing professionals' in real professional activity in recent years has been actively addressed in modern science and practice by adjusting the content and teaching methods in higher education establishments (general training disciplines) (Kruglik, 2017) and their professional development in IT companies (special courses, training, etc.), the development of metacognitive skills both at the scientific and practical level remains indefinable.

Moreover, it should be noted that according to the Education Law (p. 12), stated by the Verkhovna Rada of Ukraine from 05.09.2017 No. 2145-VIII (# 11), the mandatory components in the content of teaching students in general secondary education institutions include the formation of such (metacognitive) skills, as the ability to express an opinion verbally and in writing, critical and systemic thinking, the ability to logically justify position, creativity, initiative, ability to constructively manage risks, evaluate and make decisions, solve problems, the ability to cooperate with others.

And so far, these requirements for learning outcomes of grades 5-9 students have been reflected in the Draft State Standard for Basic Secondary Education (Source # 12) in all educational fields, including Informatics, which is essentially a propaedeutic of professional IT education. For example, by the end of grade 9, after studying the subject "Informatics" according to the Concept of "New Ukrainian School" the student should have the following skills:

- to argue and defend one's position, using various resources, comparing alternative views from several information sources;
- experiment with ideas and resources, solutions and technologies when creating information products, refining them for expression, solving learning and life problems, creating values or influencing the community;
- to show persistence, adaptability, initiative, openness to creative experimentation during the development of software projects;
- offer solutions for real-world and virtual-based computer simulation;
- handle challenges, eliminate mistakes and use them as an opportunity to improve the project or develop it;
- composes messages based on the visual representation of data;
- explain the impact of emotions on teamwork, know and use ways to manage emotions.

Therefore, it is important that the development of metacognitive skills of IT specialists continues at the next levels of education (in higher education) and that there will be continuity in education.

The objective of the study is to determine the level of metacognitive skills of software testing specialists of Ukrainian, Russian and Belorussian IT companies and to define the problem of the need for their purposeful development.

2 Methodology and Methods.

The study was conducted among Ukrainian software testing experts during December-January 2020. The study involved 27 software testing experts working for leading IT companies (EPAM Systems, Plarium, Global Logic), ages 21 to 45 (44.4% women and 55.6% men), with the working experience in IT from 4 months to 12 years, with different professional levels (Junior -18,5%, Middle - 40,7%, Senior - 22,2%, Team Lead - 18,5%).

All of the participants in the study have higher education, 29.6% of them received education in the humanities in various specialties (journalism, variety singing, translation, management, finance), 22.2% have a technical education not related to IT (railway engineering, transportation, aeronautic engineering, marine engineering, etc.), 14.8% - mathematical education (applied mathematics) and 40.8% - IT education (software engineering, systems engineering, systems analytics, computer science, computer systems, software of automated control systems, applied IT). 100% of the interviewed specialists were trained in the area of IT companies' activities.

The methodology used in this piece of research was a mixed one combining qualitative and quantitative methods, the method of filling in the questionnaire is electronic.

For the statistical analysis of the collected data, the «IBM SPSS Statistics 23» was used.

2.1 Authorial Questionnaire

The purpose of it is to determine: the level of specialists' awareness of the activity features in the field of software testing; requirements for professional qualifications, which primarily contribute to their successful professional careers, as well as requirements for the professional training of testers in higher education institutions. The questionnaire contained open-ended questions (In your opinion, what distinguishes the activity of a software testing specialist in an IT company from other IT specializations? What are the soft skills that first and foremost contribute to a successful professional career as a software tester? Do you think that you have sufficient professional qualifications at a higher education institution to continue to work as a software testing specialist (specify why)? In your opinion, how can the professional training of future software testing professionals in higher education institutions be improved? etc.);

2.2 Metacognitive Awareness Inventory

Constructed by Rayne Sperling and Gregory Schraw (1994), the Metacognitive Awareness Inventory (MAI) is a well-established and useful assessment of metacognition. The MAI has been used in hundreds of studies, ranging from basic to applied research. It is a 52-item inventory with two broad categories (knowledge of cognition and regulation of cognition), with several sub-categories:

- knowledge about cognition - declarative knowledge, procedural knowledge and conditional knowledge;
- regulation of cognition – planning, information management strategies, comprehension monitoring, debugging strategies and evaluation (Schraw, Dennison, 1994).

Declarative knowledge is the factual knowledge the specialist needs before being able to process or use critical thinking related to the topic, knowledge of one's skills, intellectual resources, and abilities (knowing about, what, or that). Procedural knowledge is the application of knowledge to complete a procedure or process, knowledge about how to implement cognitive procedures (e.g., strategies), know the process as well as when to apply the process in various situations. Conditional knowledge - the determination under what circumstances specific processes or skills should transfer, knowledge about when and why to use learning procedures, application of declarative and procedural knowledge with certain conditions presented. Regulation of cognition is the ability to regulate cognitive activity at different stages:

- planning - planning, goal setting, and allocating resources before learning;
- information management strategies - skills and strategy sequences used to process information more efficiently (e.g., organizing, elaborating, summarizing, selective focusing);
- comprehension monitoring - assessment of one's learning or strategy use;
- debugging strategies - strategies to correct comprehension and performance errors;
- evaluation - analysis of performance and strategy effectiveness after a learning episode.

2.3 The Scale of Self-Assessment of Metacognitive Behavior by D. LaCosta.

This technique was developed in 1998 and is a short questionnaire, fairly easy to use and interpret. Subjects are required to assess the cognitive strategies they use. The technique is recommended for use as an indicator of the level of metacognitive strategies development in the situation of purposeful learning and for the diagnosis of the metacognitive strategies of the professionals who use them in their work. The metacognitive strategies indicated in the methodology reflect the basic mechanisms of metacognitive skills actualization (objectification, schematizing, normalization, verbalization, reflection). It is also important that this technique is didactic in nature and stimulates thinking and reflexive activity of an interviewee, leads to a problematic situation, gives cause for reflection on existing metacognitive mechanisms/strategies. The scale consists of 12 statements that determine the degree of metacognitive skills generalization - the frequency of their use.

3 Results

According to the results of the study, the following data was obtained. Among the specific features of the software testing specialist's work in IT companies, the respondents named (by frequency of statements):

1. responsibility for the quality of the product at all stages of its development, a specialist is a "quality engineer", which in turn requires analysis and the maximum of software inspections to ensure that the product is working properly;
2. metasytemic features, since it requires a professional programming competency of a tester (having programming experience, knowing programming code), and as well as the competencies of a business analyst and a project manager (knowing its organizational structure, having organizational and communication skills);
3. the need to analyze the product from several sides: from the customer's point of view, in addition to that - the software developer, and, what is more important - from the perspective of the user of the product;
4. creativity, since it requires a constant search for ways to test and optimize the test coverage.

The main non-technical professional qualities of the software testing specialist, according to the respondents, were:

- communicative: communication, sociability, the ability to negotiate, the ability to put oneself in the position of others, the ability to seek and find compromises;
- responsibility;
- self-organization, the ability to overcome stress, the ability to perform repetitive mundane tasks;
- the ability to solve problems, the ability to make decisions;
- attentiveness, the ability to see the little things, thoroughness;
- the ability to work in a team;
- logic, analytical thinking, critical thinking, creativity, ability to formulate thoughts;
- goal setting and the ability to plan activities;
- organizational skills;
- the ability to present the results of work;
- desire for self-development;
- foreign language proficiency.

Among the non-technical professional qualities related to metacognitive the interviewees named: the ability to solve problems (26%), decision-making ability (18.5%), goal setting (11%) and the ability to plan activities (9%), as well as generating hypotheses and risks assessment (7.4%).

These results are confirmed by the main employers' non-technical requirements to a software testing specialist (based on the analysis of the positions) (Faheem Ahmed, Luiz Fernando Capretz, Piers Campbell, 2015), namely:

- responsibility, that is a complete control of the task outcomes, including not only an individual part but also the final team result;
- communication, that is the ability to formulate thoughts, trying to be polite and avoiding potentially dangerous and destructive topics;
- stress resistance - the ability to withstand escalations (for example, the client's clear dissatisfaction with the work), the ability to withstand abnormally high workload and recover after short breaks;
- mentoring - the ability to transfer their knowledge and experience to other team members, to direct the development of young specialists in a beneficial for the company direction;
- planning and self-management - the ability to prioritize and carry out current tasks on time; without the need for constant managerial supervision;
- teamwork - the ability to conduct effective and productive activities in collaboration with colleagues, achieve common goals and better utilize shared resources.

Regarding the connection between the attained professional level of software testing experts and the level of development of their metacognitive skills, the results of the Metacognitive awareness inventory application show data indicating a shift in the approximate values of software testing experts' metacognitive awareness from 194 to 209 points, that is, the overall level is higher than the overall adult sample rate (Karpov, 2018).

Given the fact that metacognitive skills ensure successful completion of professional tasks, it was logical to assume that there is a connection between the level of development of metacognitive skills (metacognitive awareness) and the professional level of software testing professionals in IT companies. However, against all expectations, the obtained rate of Spearman correlation is very insignificant ($r = 0.045$) (Table 1). When dividing the sample into two polar groups (the lower professional level - junior - middle and the higher professional level - senior - team lead), metacognitive awareness indicators were also statistically insignificant. Therefore, it can be concluded that both software testing professionals who have a professional junior-middle level and those who have a senior-team lead level have both high and low levels of metacognitive awareness. Thus, as the results of the study showed, as to the achieved professional level in IT companies experts in general and groups with lower and higher professional levels are not characterized by quantitative differences in metacognitive awareness. However, as the analysis showed, with minor general differences, metacognitive control of professionals with lower and higher professional levels is implemented by different strategies. Thus, calculating the correlation across the different subscales of Metacognitive awareness inventory showed that for senior-team lead professionals, the leading metacognitive strategies that ensure their effectiveness are the reflective assessment of their activities, their performance, and the development of alternative decision options, and for junior - middle - planning and reliance on available acquired knowledge.

Therefore, it can be argued that significant metacognitive soft skills of software testing professionals are those that provide metacognitive control at all stages of their professional activity - from goal setting and to reflectively evaluating its results and

determining ways to adjust its progress. It is the metasytem, the relevance, the presence at all stages of solving professional problems that ensures the successful professional development of these specialists, their career growth.

Table 1. The value of Spearman correlation coefficients between professional attainment and metacognitive skills of software testing professionals

	professional level			Metacognitive behavior (n=27)
	all (n=27)	Junior-middle (n=15)	senior-team lead (n=12)	
metacognitive involvement	0,045	-0,01	0,05	0,709
metacognitive behavior	0,105	-0,066	0,053	

To identify the main metacognitive strategies most commonly used by software testing professionals in their professional activity, a 12-factor analysis of metacognitive skills was conducted using the method of Metacognitive Behavior Self-Assessment Scale provided by LaCosta.

To determine the number of contributing factors Cattell criterion was used. Kaiser-Meyer-Olkin Measure of Sampling Adequacy amounted to 0.618, which indicates that the factor model of the correlation matrix of this set of variables is satisfactory. Bartlett's test of sphericity gave the result that equals 0.000, which indicates the existence of a correlation between the variables of the source array and the possibility of grouping them by the tightness of the correlation. Four relatively independent factors were identified to explain 71.3% of the variations in the measures on the scales (Table 2). This indicator is considered sufficient for psychological research.

The skills that are included in the first factor, explaining 23.83% of the total variance and has a factor weight of 2.860, are the most influential on the metacognitive behavior of software testing professionals. It comprised: 1) overcoming subjective constraints (awareness of the ability to solve complex problems and persistent conscious search for solutions) (0.904); comprehension of achievements (correlation of subjective achievements with objective feedback) (0,893); strategic planning (purposeful planning, monitoring, and evaluation of activities) (0,699); formulation of questions (conscious formulation of questions that address gaps in certain areas of knowledge) (0.644). These skills are the most requested for a group of high-level professionals (senior-team lead).

The second factor (19.26% of the total variance, factor weight of 2,311) comprised:

- modeling (construction of mental representations of experience) and schematizing (construction of schemes of phenomena and processes) (0.802);
- definition of terminology (formulation of precise definitions for initially blurred, ambiguous or poorly understood terms) (0,690); paraphrasing and summarizing the information received (reframing ideas that come up) (0.639); conscious decision making (foreseeing the effect and consequences of each choice) (0.580).

The third factor explains 15.75% of the total variance and has the factor weight of 1,890. It includes the following indicators: detection of cognitive behavior (definition of used cognitive strategies and their importance for solving the problem) (0,775), differential evaluation (reflective evaluation of their actions according to various criteria) (0,760). The abilities included to the fourth factor (explains of 12.43% of the total variance and has factor weight of 1,492) - keeping a diary (writing down your personal thoughts) (0,845) and role-play (playback of partner/customer position of the communication, imaginative dialogue with him) have the least impact on metacognitive behavior of the testers.

Table 2. Inverted component matrix (factor separation method - principal component method, rotation method - varimax with Kaiser normalization)

	Component			
	1	2	3	4
overcoming the subjective restrictions	,904	-,113	,262	-,043
comprehension of achievements	,893	,171	,143	-,093
strategic planning	,699	,280	-,117	,332
formulation of questions	,644	,508	,078	,252
modeling	-,083	,802	-,109	,172
definition of terminology	,313	,690	,170	,137
paraphrasing and summarizing	,158	,639	-,453	,031
decision making	,260	,580	,479	-,291
definition of cognitive behavior	,219	,067	,775	,002
differential evaluation	,022	-,099	,760	,133
keeping a diary	-,071	,230	-,070	,845
roleplay	,301	-,029	,350	,665
Factor load	2,860	2,311	1,890	1,492
Percentage of total dispersion	23,832	19,255	15,748	12,433

Regarding the consistency of the results obtained by the application of the Metacognitive Awareness Inventory and the Metacognitive Behavior Self-Assessment Scale provided by LaCosta, a statistically significant stable positive correlation of metacognitive awareness indicators and metacognitive behavior of professionals was found ($r=0,709$). Therefore, the higher the level of metacognitive awareness of respondents on the counts of metacognitive knowledge and metacognitive regulation, the more often they use metacognitive skills of the first and second factors.

Regarding the determination of changes that have to be made in the professional training of software testers for their successful professional activity, according to the survey results, 96.3% of software testing experts believe that there is a significant shortage of professional training for successful performance in IT companies in higher education institutions. Moreover, 59.2% of them stated that training programs in higher education institutions are inconsistent with the real professional activity of the software tester, that higher education represents a potential start, which should be compensated

by long independent preparation for such activity, as well as training directly in the IT company.

89% of respondents said that training in higher education institutions does not ensure the formation of soft skills for future professionals, which causes the need for additional learning, doing special training, courses both within the IT company and externally (training centers, distance courses, etc.).

Among the measures to improve the training in higher education institutions, experts offered the following: internships for future testers in IT companies, on real projects (89%), enrollment in software testing courses for software engineers (59.2%), teaching professional courses exclusively by expert-practitioners in IT companies (40.7%), decision-making in real laboratory situations and tasks (introduction of contextual approach) (40.7%), rejection of outdated methodologies (18.5%).

4 Conclusion

The conducted research allows us to formulate the following conclusions.

Firstly, among employers' requirements for software testing professionals, apart from technical training, so-called non-technical, non-professional requirements or soft skills play an important role, which, in addition to communicative and teamwork skills, responsibility, stress management, include such metacognitive abilities as goal-setting, foreseeing, decision-making, planning and programming of personal activity, as well as carrying out its reflective analysis. It is metacognitive skills that monitor and manage the cognitive, emotional, and regulatory processes of the professional activities of software testing professionals, ensuring their performance and professional growth.

Secondly, the specific features of the professional activity of software testers in IT companies, as the experts surveyed stated, are responsibility for the quality of the product at all stages of its development, meta-systemic nature, multi-positioning, creativity. Their successful professional activity depends not only on technical, specialized knowledge and skills but also on non-technical ones, which include such metacognitive skills as problem-solving, decision-making skills, goal setting and planning skills, as well as generating hypotheses and risks assessment skills. This is confirmed by the lack of higher education of the surveyed testers in not only the field of IT but also by the lack of technical higher education in general.

Thirdly, empirical research shows that, in terms of professional level in IT companies, professionals as a whole and groups with lower and higher professional levels are not characterized by quantitative differences in metacognitive awareness. However, metacognitive control of professionals with lower and higher levels of professionalism is implemented by different strategies: for senior-team lead specialists, leading metacognitive strategies that ensure their performance are reflective assessment of their personal activity, its effectiveness and development of alternative solutions, and for junior - middle - level professionals, planning and relying on acquired knowledge. That reflects the importance of the professional growth of specialists in testing software metasystem, relevance, and representation of their metacognitive skills at all stages of solving professional problems. Factor analysis shows that the greatest influence on the

metacognitive behavior of software testing professionals and their successful professional development is made by the ability to overcome subjective limitations, reflect on achievements, strategic planning, formulate questions. Metacognitive skills such as keeping a diary (writing down one's thoughts) and role-playing (putting oneself on a partner/client's position, imaginary dialogue) are of the least influence.

Fourthly, the training of IT professionals in Ukrainian higher education institutions serves mainly as a potential start and requires a time-consuming self-study, as well as training directly in an IT company. Given the lack of a separate direction of training for software testing specialists in Ukrainian universities, the IT sector needs to develop and implement appropriate higher education standards, which in turn will ensure the development of metacognitive skills for future professionals.

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Analysis of Ergonomic Indicators and Compliance with the Principles of the Instructional Design of Education Courses in Adaptive Learning Systems

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Abstract. The article is devoted to the research of the instructional design features of the education courses in the adaptive training systems. The instructional design as a modern didactic direction in the use of modern information technologies has been considered and investigated. The increasing role of the instructional design has been defined in conditions when the learning environment and learning itself are transferred into the electronic environment, when it is necessary to develop the most efficient, comfortable and at the same time, effective training systems and methods.

The position that instructional design can be considered an essential component should be taken into account when designing modern education courses in the electronic environment has been justified. The compliance with the principles of usability and user interface ergonomics of the developed educational materials by means of adaptive learning systems Knewton, RealizeIt, CourseArc, Brightspace Leap, Revel, Open Learning Initiative, and the Generalized Intelligent Framework for Tutoring has been reviewed. The conditions of the designing of electronic educational resources based on the instructional design that enable to convey the educational material more effectively and to create the conditions for better learning by students have been defined.

Keywords: Adaptive Learning System, Instructional Design, User Interface, Usability, Ergonomics.

1 First Section

1.1 The Statement of Issue

The issue of improving the teaching methodology in educational institutions remains highly relevant for a long period of time, particularly the teachers attention is focused on e-learning itself and adaptive learning systems. With the transition to electronic learning, educators need to introduce new forms and methods of information, consid-

ering that information in its visual perception can be adsorbed in easier and prolonged way.

The instructional design plays an important role in providing a more efficient, productive and qualitative process of learning. The instructional design forms a coherent system of goals, learning material and available knowledge transfer tools. The instructional design is primarily aimed at filling the course with meaningful information, forming a sequence of presentation and introduction of modern ways of presenting educational material. However, the indicators of usability and ergonomics are equally important in the instructional design of educational materials for the electronic environment in correspondence with existing dependency between easiness of the education courses using and the quality of the material acquisition by the students. This is especially important in e-learning, where interaction between students, teachers and content is ensured not face-to-face, but through information and communication technologies [1].

The appropriate attention should be given not only to the content of the course, the methods and techniques to be used in the e-learning process, but also to the visualization of the educational content, to the indicators of ergonomics and usability of the platform on which the course is located. These elements should act in harmony in order to ensure high quality training. Taking into account the relevance of e-learning, the relevance of usability, ergonomics and instructional design in the development of e-learning materials for education courses is becoming increasingly important, especially in the context of the Stanford University research of the identifying factors that affect people's trust [2].

Nowadays, the field of adaptive learning is relevant in pedagogy, which involves the use of appropriate software, that allows the formation of personalized learning. Due to the fact that the methodology for using adaptive learning systems remains poorly developed, and based on the foregoing, it is necessary to study the existing adaptive learning systems for compliance with indicators of usability and ergonomics in the instructional design of educational materials.

1.2 Problem State of the Art

Thorough research into the study of instructional design has been reflected in the works of many foreign and domestic scholars, in particular S. Denysenko [3], A. Uvarov [4], B. Mergel [5], V. Tymenko [6] and others. The use of instructional designers with expertise in pedagogical strategies and technology for eLearning has been considered in the research [7]. The work [8] is devoted to the implementation of Universal Design for Learning (UDL). Visualization of educational information as a tool for the development of cognitive learning actions is proposed to use in the researches [9; 10]. The issue of the basics of visual design has been addressed in [11, 12; 13] and in the online course design guideline [14, 15, 16]. Usability issues in instructional design of Massive Open Online Courses were considered in the research [17]. The use of learning environments in traditional and distance learning has been discussed in works [18, 19, 20] and others. Researches that address some aspects of the use of ICT in the educational process [21, 22, 23, 24].

The aim of article: To analyze the ergonomic indicators and compliance with the principles of instructional design of education courses in adaptive learning systems.

2 The Results of Research








Usability is a concept that can be applied to the analysis of the user interface of resources, which determines their convenience and ergonomics while using. The design processes of Human Centred design are regulated by The British Standard / ISO Standard [25] and define usability as the extent to which a product can be used by specified users to achieve specified goals with effectiveness, efficiency and satisfaction in a specified context of use.

Analyzing the usability of the user interfaces of the developed education courses in adaptive learning systems, we followed the recommendations given in J. Nielsen's classic book "Designing Web Usability" [26], in order to analyze the offered ergonomic indicators. Such features as design, especially taking into account its "flexibility" or "rigidity", page length; availability and interface of search tools; the nature and the means of the navigation procedure realization were analyzed. The proposed list of indicators and characteristics for the formation of criteria, by which the ergonomic quality of the interface was analyzed, has also been expanded with the indicators that are important due to the principles of the instructional design of educational materials. The particular attention was paid to the possibility of integration of various multimedia fragments (video and audio accompaniment, integration of presentation material, integration of interactive elements, etc.) and to the functionality of testing elements (providing an individualized interpretation of false answers, cards, etc.). Equal emphasis was placed on the possibility of individualization and the design branding of educational materials, which would help to create a positive image of the educational institution, on the basis of which the system of adaptive learning is implemented.

The indicators' characteristics of usability, ergonomics and the instructional design of education courses in the following adaptive learning systems: Knewton, RealizeIt, CourseArc, Brightspace LeaP, Revel, MyLab, Open Learning Initiative (OLI) and Generalized Intelligent Framework for Tutoring (GIFT) were analyzed and researched. Combined comparative analysis is given in **Table 1**.

The following reference designations ● - the best indicator, ◐ - fragmental availability (not perfect), ○ - absent have been chosen.

Table 1. Comparative Analysis of Usability Indicators and Ergonomics of Instructional Design of Adaptive Learning Systems Training Courses

Characteristics	Adaptive Learning Systems						
							
	Knewton	Realizeit	CourseArc	Brightspace Leap	Revel	OLI	GIFT
Design							
Moderate colour scale	●	○	●	●	●	●	●
Minimalistic design	●	◐	●	●	●	●	●
Adaptation to mobile devices	●	○	●	●	●	○	◐
Course branding	○	○	●	◐	○	●	◐
Navigation							
The User Controls Navigation	●	○	●	●	●	◐	●
Search Capabilities	●	◐	●	●	●	◐	●
User-Contributed Content	●	○	●	●	●	◐	●
Applet Navigation	●	◐	●	●	●	◐	●
Topic hierarchy	●	●	◐	●	◐	◐	●
Skills system	○	●	○	○	◐	○	○
Progress statistics							
Progress Bar	●	◐	○	●	●	○	○
Achievement detailing	●	○	◐	○	●	○	○
Educational content							
Books Management	●	◐	●	●	◐	◐	●
Curriculum/syllabys Management	●	○	●	●	○	◐	◐
Library Management	●	◐	●	◐	◐	◐	●
Image support	●	●	●	●	●	●	●
Video support	●	●	●	●	●	●	●
Audio support	●	○	●	◐	●	●	◐
Presentation support	●	○	●	○	○	○	●
Interactive elements	◐	○	●	○	●	○	○
Testing functional	●	◐	●	●	●	◐	◐
Storyboarding	○	○	○	○	◐	○	○
Educational gamification	○	○	◐	◐	◐	○	○

Consider the adaptive learning systems that were the subject of detailed review.

2.1 Knewton

Knewton is an online service for creating courses using adaptive learning technology. The main page contains a list of courses, buttons to help sorting it, and a search for courses. Search and sorting is one of the most convenient functions. This helps to find the right course quickly by spending the least amount of time. The minimal colour and inactive contrast between the background and the font do not overwhelm the user's attention.

It should be noted that the courses for each user are personalized (**Fig. 1.**), and depend on the answers to the tests and the number of completed tasks. Usability provides quantitative indicators of course completion.

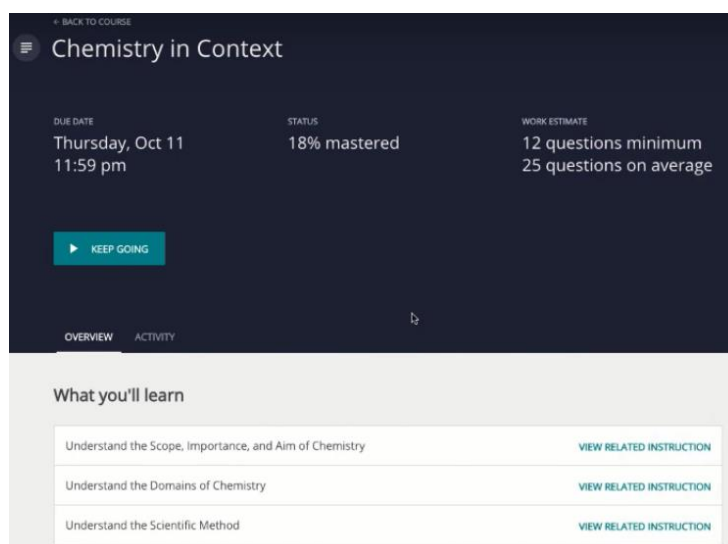


Fig. 1. A personalized page of Knewton adaptive education course

Particularly, the textual content can be accompanied with video content, graphs, charts, and other visualizations of educational materials that enhance memorization. According to the results of mastering each block of material, testing was implemented to assess the level of understanding of the educational material. In addition, the functions of Content Feedback and More Instruction have been implemented to improve understanding of the material.

In the course of testing in the case of a false answer, the student has quick access to the personalized fragment of material, which explains the correct answer and gives the opportunity for complete understanding of the context. If the false answer belongs to the priority topic or contains a key skill, the student is instructed how to study the topic, that he does not understand, more thoroughly to enhance understanding (**Fig. 2.**).

The screenshot displays a user interface for a Knewton adaptive education course. At the top, it shows the user's name 'Knew Student' and the course duration 'September 25, 2018 - January 4, 2019'. Below this is a 'SCHEDULE' section with tabs for 'SCHEDULE' and 'INSTRUCTORS NOTES'. The schedule lists several quizzes and tests with their respective dates and completion status:

- Advanced Ratios: November 15 (Completed, indicated by a green checkmark)
- QUIZ: Percent Increase of Decrease Quiz: November 30 (Not completed, indicated by a right arrow)
- Percent Increase of Decrease: December 10 (Not completed, indicated by a right arrow)
- QUIZ: Advanced Ratio Quiz: December 21 (Not completed, indicated by a right arrow)
- TEST: Mini test 1: December 11, 10:22 am - December 12, 8:59 pm (Not completed, indicated by a right arrow)

Below the schedule, two question examples are shown. The first question asks 'Explain why chemistry is sometimes called "The Central Science"'. The user's answer is marked as incorrect, and the correct answer is 'Chemistry is highly interconnected with so many other scientific disciplines.' The second question asks 'Chemistry is best defined as the study of which of the following?'. The user's answer is marked as correct, and the correct answer is 'the properties and interactions of matter'.

Fig. 2. A personalized page of Knewton adaptive education course

The results of testing and completed tasks determine the level of education course acquiring and define the need for additional practical tasks and tests. It is possible to increase the level of discipline acquiring before the completing the education course.

A progress bar provides the convenience for understanding your own level of course skills acquiring. It is important to note that the progress bar not only accumulates the level of professionalism in the education course, but can also decrease depending on the activity on the course. For better understanding of the shift direction of the bar progress, it is possible to detail own progress (**Fig. 3**).

The screenshot displays a user interface for a Knewton adaptive education course. At the top, it shows a 'BACK TO ASSIGNMENT OVERVIEW' button and the course title 'Chemistry in Context'. Below this is a 'Your Mastery Breakdown' section with a progress bar showing '13% mastered'. The 'Learning Objectives' section lists four objectives, each with a corresponding progress bar:

- Perform Specific Gravity and Density Calculations
- Identify and Use the SI Units for Time and Temperature
- Understand How to Use the SI System for Units Names and Abbreviations
- Identify and Use SI Units for Length, Volume, and Mass

Fig. 3. A personalized page of Knewton adaptive education course

Based on the analysis of usability indicators it is possible to conclude that the Knewton Adaptive Learning System is easy to use, has a friendly interface, a well-designed and thoughtful structure that matches the functional needs of users. It has a user-friendly and intuitive navigation and intuitive user interface.

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2.2 RealizeIt

With RealizeIt, a user can create their own, personalized learning experiences that improve student engagement, readiness and success. Prior to the course creation, it is possible to create a curriculum that is a set of goals or skills the student must achieve during the course. It may be designed to describe the expected learning outcomes, but may also include information regarding the resources by which these results can be achieved. The curriculum can include the humanities, social sciences, STEM subjects, linguistics, used in the process of lifelong learning - actually any branch of knowledge for learning. The area of knowledge of the curriculum is defined using a hierarchical view (Fig. 4).

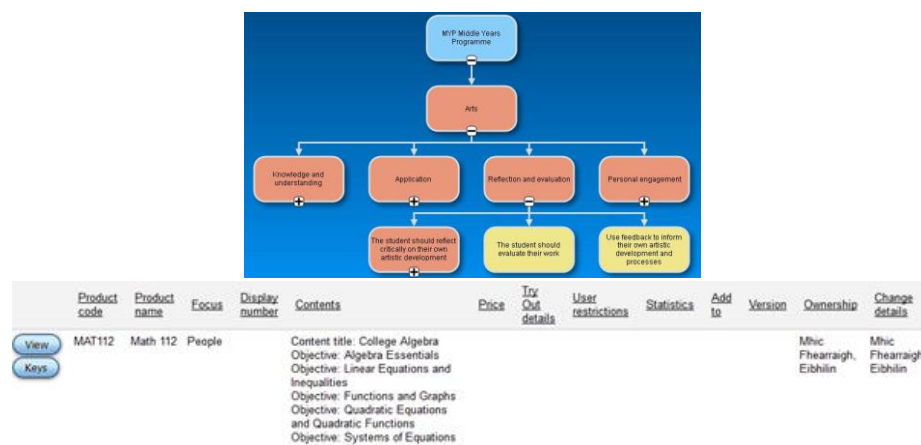


Fig. 4. A personalized page of Knewton adaptive education course

When students interact with the system, it captures their progress, knowledge growth, lost knowledge, strengths and weaknesses and learning preferences in real time. They provide the teacher with a detailed understanding how each student learns the material and allow the teacher to predict their success in the future (Fig. 5).

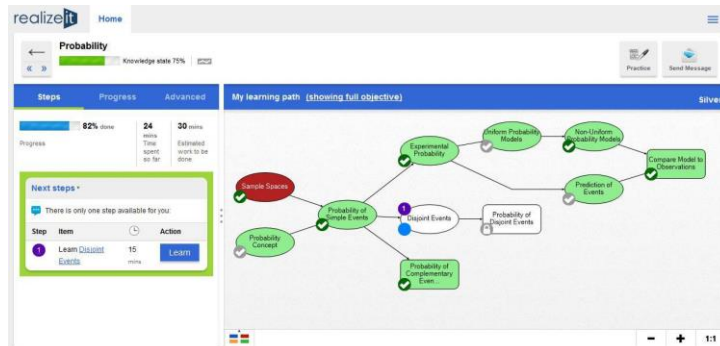


Fig. 5. The achievement progress in the course of completing the RealizeIt curriculum knowledge space

The convenience of educational material acquisition in the adaptive learning system RealizeIt is added by “My learning path” that provides information about the completed course material, its links to other topics and tasks, and the achievements after each topic completion. The individual progress bar with material acquisition dynamics is also visualized. The process of uploading the educational materials also provides the opportunity to include accompanying multimedia materials. But it should be noted that the interface of the education courses is overloaded with color scale and a large number of controls and graphs (Fig. 6.), which demonstrate the dynamics of the material acquisition, which creates the prerequisites for dispersing attention from the educational material.

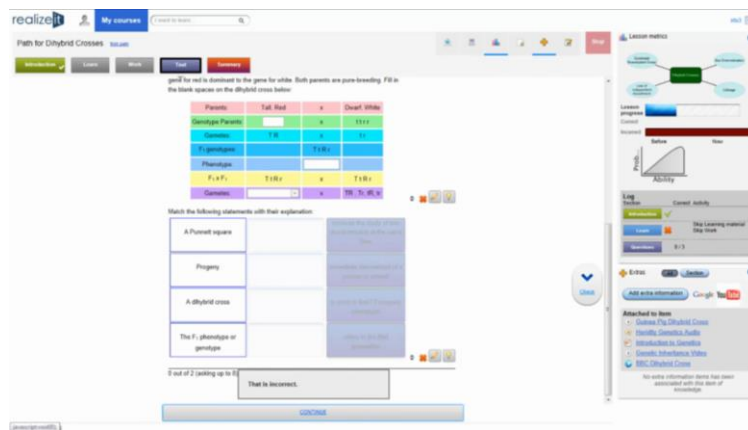


Fig. 6. RealizeIt educational element interface

2.3 CourseArc

The resource has ready-made templates and icon banks that are easy to customize. The topic editor allows to upload a banner image or logo and choose the desired color solution, enabling to brand the education course for an affiliated institution (Fig. 7).

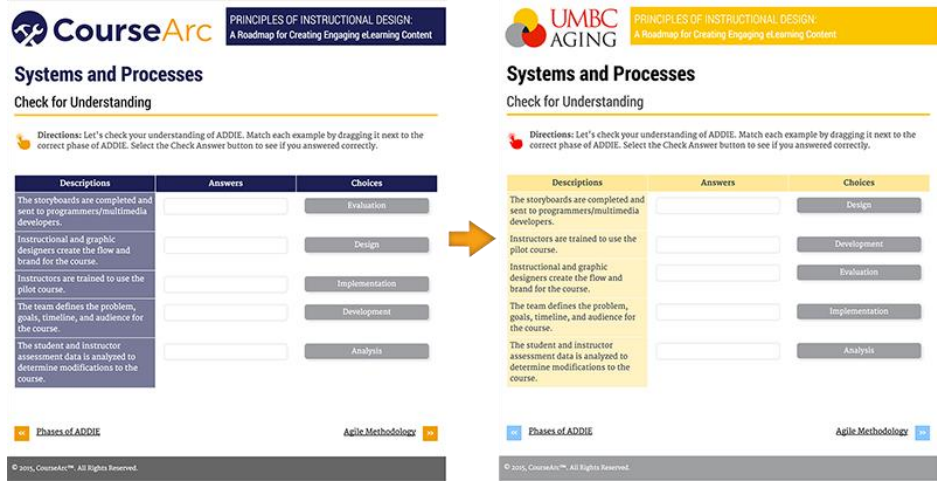


Fig. 7. The achievement progress in the course of completing the Realizeit curriculum knowledge space

CourseArc also provides powerful capabilities for not only test controls designing but also for creating drag-and-drop interactive elements for quiz controls, which adds an additional interactive learning experience (Fig. 8).

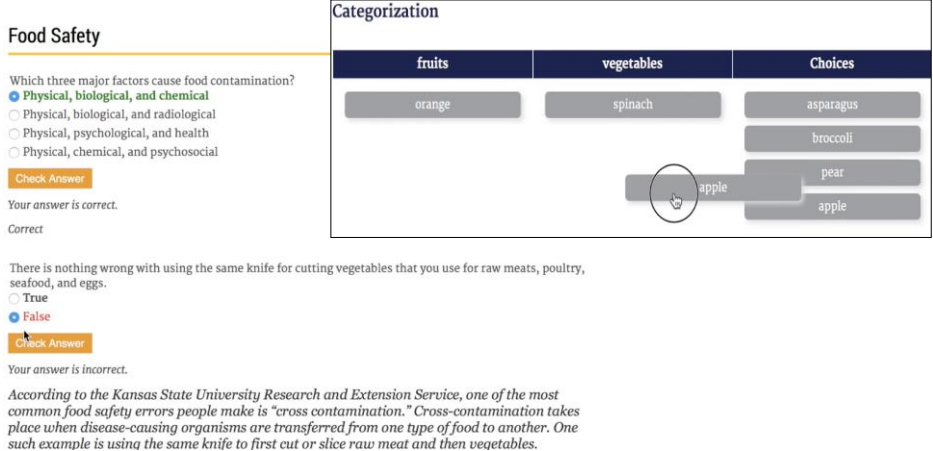


Fig. 8. Example of simple testing and interactive quiz elements in CourseArc

2.4 Brightspace LeaP (Desire2Learn)

The control of students' activities with Brightspace Leap allows to see student's weaknesses, according to his results, and automatically recommends materials that can help. The Brightspace Student Success System enables to identify potential student problems through predictive analysis and visual diagnostics, and to provide students with the help they need in a timely manner.

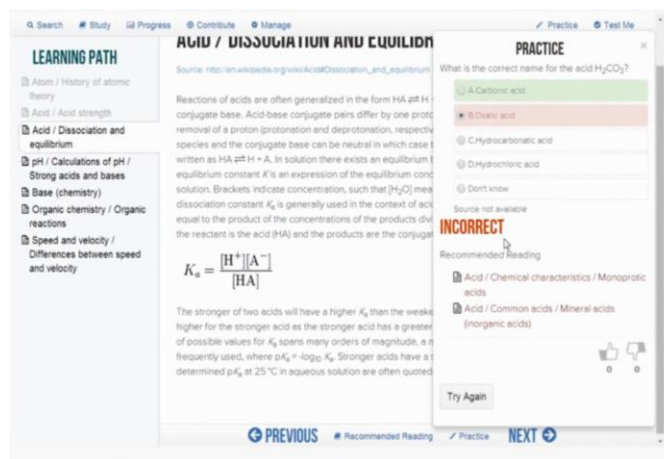


Fig. 9. Example of simple testing and interactive quiz elements in CourseArc

The user interface (**Fig. 9.**) allows creating interactive lists and courses using drag-and-drop. In particular, the OpenDyslexic font, that was designed specifically for people with dyslexia, should be stressed on as it intended to make content more accessible to a wider audience: choosing this font makes the course text easy to read.

2.5 Revel

Submitting Revel courses is easy and convenient, saves time and allows students to use their courses even more effectively. On the “Recommendations” page, users can find an advice on how to plan their course (**Fig. 10.**).

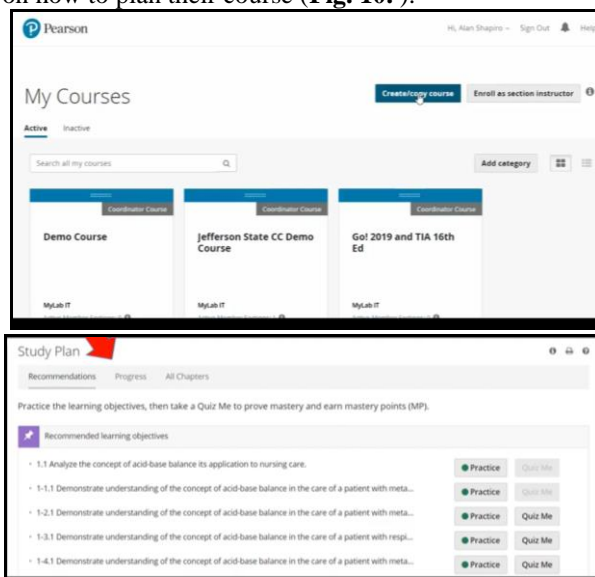


Fig. 10. The interface of the course choice page of page of the individual Revel curriculum

Among the opportunities and benefits that should be noted are effective access (single sign-on technology allows teachers and students to enter login once for all course resources); a unified assessment list with easy updates (grades for all MyLab & Mastering tasks are automatically submitted to the Blackboard Learn Assessment Center; upon request, Revel scores can be synchronized to allow teachers and students to track class progress in one location); comfortable workflow (having access to Pearson content from the course content area allows teachers to easily find and adapt content to their usual Blackboard Learn workflow) and student data confidentiality (student confidentiality is guaranteed in full compliance with student privacy standards).

In particular, a powerful and functional system of interactive quiz controls (Fig. 11.), the ability to create and use interactive maps, flash cards, quizzes that provide learning with the elements of gamification should be mentioned.

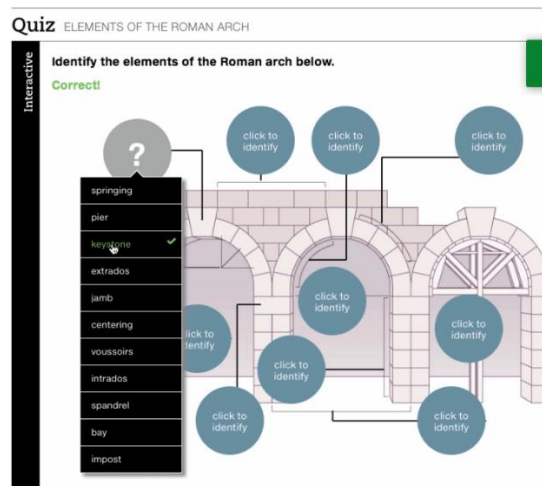


Fig. 11. An example of a Revel online quiz test

2.6 Open Learning Initiative (OLI)

The Open Learning Initiative (OLI) is presented by developers as a “cognitive mentor” and characterizes the system as a computer-based learning environment formed on cognitive principles and whose interacting with students is based on the discussion difficult questions with the mentor. The system does not stand out with bright design and is characterized by a moderate minimalistic color scale, but has a set of most necessary functions to work on the instructional design of the education courses and materials at its disposal (Fig. 12.).



Fig. 12. Course page interface and the fragment of the Open Learning Initiative (OLI) educational material

2.7 Generalized Intelligent Framework for Tutoring (GIFT)

GIFT enables to create adaptive courses both online and in an application downloaded to your computer (Fig. 13.).

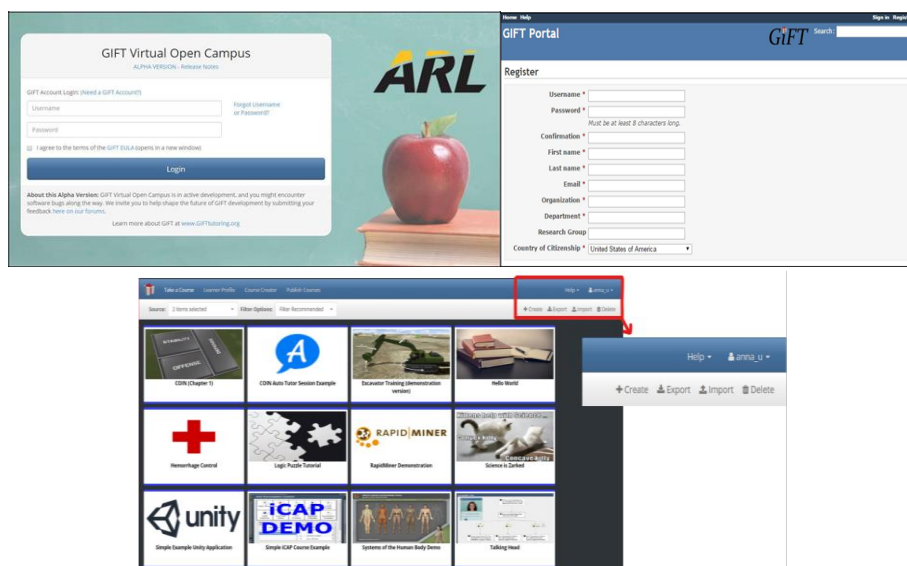


Fig. 13. Generalized Intelligent Framework for Tutoring (GIFT) interface

To the educational material content except the text block, tables and lists, links or web pages can be added. The possibility to use video and presentations makes the course more packed and entertaining. Simple GIFT tests are used to consolidate and to check gained knowledge. All list components support drag and drop function.

The main GIFT function is the possibility to add VR-Engage and Unity files to check students' knowledge.

In addition, given the analysis of the indicators of ergonomics and compliance with the principles of the instructional design of education courses in adaptive learning systems, the introduction of such education courses in the process of learning can provide more opportunities to diversify and increase the students' interest. The theoretical analysis of ergonomic indicators of the education courses, developed by means of existing adaptive learning systems, shows that the efficiency of the instructional design of educational materials is increased. Summing up, it must be recognized that the focus on increasing the level of ergonomic indicators and elements that follow the principles of the instructional design of education courses is an objective system response to the needs of modern students.

3 The Conclusion

Therefore, the use of new information technologies, in particular adaptive learning systems, provides wide opportunities for a significant quality improvement of the process of learning, increases both the level of knowledge acquisition and the learning interest itself. The instructional design of e-learning based on the principles of usability and ergonomics can be considered as an essential element that should be taken into account when designing modern learning tools. Based on the instructional design models, electronic educational resources will be able to convey educational material more effectively and create the conditions for its qualitative acquisition by learners. According to the analysis results of the ergonomic indicators and compliance with the principles of the instructional design of education courses in adaptive learning systems, it should be concluded that each of the systems has its own peculiarities and functional capabilities, so the selection of a suitable system of adaptive training for the construction of training courses should be made due to the needs that arise as a result of the instructional design of each individual education course. The prospects for further research include the establishment of methodological recommendations for taking into account the ergonomic indicators and applying the principles of the instructional design in the development of education courses in adaptive learning systems.

4 Funding

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Use of AR/VR Technologies in the Development of Future Specialists' Stress Resistance: Experience of STEAM-Laboratory and Laboratory of Psychophysiological Research Cooperation

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Abstract. The scientific article deals with the analysis of peculiarities of the use of innovative AR/VR technologies in the process of developing future specialists' stress resistance. Based on the analysis of the introduction of AR/VR technologies in the context of the implementation of a competency-based approach to higher education; modern studies on the impact of augmented reality on the emotional states and physiological features of a person in a stressful situation, the experience of cooperation of students and teachers at the Laboratory of Psychophysiological Research and STEAM-Laboratory has been described. Within the framework of the corresponding concept of cooperation, an integrative approach to the process of personality's stress resistance development has been designed and implemented. It is based on the complex combination of traditional psycho-diagnostic and training technologies with innovative AR/VR technologies. According to the results it has been revealed that the implementation of a psycho-correction program with elements of AR technologies has promoted an increase of the level of personality's emotional stability and stress resistance. The level of future specialists' situational and personal anxiety has decreased; the level of insecurity, inferiority, anxiety about work, sensitivity to failures has also decreased; the level of flexibility of thinking and behavior, ability to switch from one type of activity to another one has increased; general level of personality's adaptive abilities has also increased. The perspectives of further research include the analysis of the impact of AR/VR technologies on the future professionals' psychological characteristics in order to optimize the process of implementing a learner-centered approach into the system of higher education.

Keywords: AR/VR technologies, Stress resistance, Professional training.

1 Introduction

Trends in the development of modern society, enhancement of computer technologies, globalization and informatization affect all spheres of social life, including higher education. The significance, aim and mission of modern education is not just the acquisition of basic knowledge and development of necessary competencies, it is the also a development of a cultural code, an independent approach to the acquisition of new knowledge, cultural values, new forms and activities. Information culture and awareness of the use of innovative augmented reality elements are some of the most important and basic competences in the process of training of future specialists, who are competitive, capable of self-realization, professional and emotional stability in the world of unstable socio-economic conditions of society. The use of the opportunities of augmented reality in education can regenerate the process of visual perception of necessary information, simultaneously involving person's cognitive and sensory systems in this process. Reproduction of some processes for visual representation in real dimensions gives an opportunity for complex perception and holistic immersion into the phenomenon under study [21]. The key characteristics of the modern educational process in higher education are: digitalization of the educational environment with a focus on the individualization of the educational process; development of adaptive technologies, technologies of electronic and mobile learning, means of identification and personalized access. All these characteristics contribute to the design of educational process models based on the development of the individual educational route of a student [16]. In accordance with the transformational information processes in education, there is a change of competence-based, personality-oriented model of future specialist's training. But the issue of the research of impact of innovative AR technologies on the mental characteristics and adaptive abilities of the individual remains quite extensive and uncovered [35]. A number of issues related to the identification of the features of the use of modern AR technologies and VR technologies for the development or stimulation of certain mental functions raises the need to create a continuum of multidisciplinary research programs [28]. The urgent issues are to determine the features of the impact of AR technologies and VR technologies on the future specialist's psychological features, in order to improve the capacity and construction of a new paradigm for future professionals' training, taking into account changing conditions of existence of modern society.

2 Literature Review

Analysis of the latest research and publications. J. Bylenson, O. Voiskunsky, S. Karelov, P. Kenney, N. Liberati, P. Milgram, G. Riva, V. Selivanov, L. Selivanov, M. Slaughter, E. Paulet J. Postil, R. Beringer, P. Donnelly, S. Fein-ra, S. Julier, B. McIntyre, and others were engaged in the study of virtual and augmented reality possibilities. In particular, the works of N. Grael, E. Guinters, H. Martin-Gutierrez, D. Perez-Lopez, M.T. Restivo, T. Rizova, J.-M. Sotata, O. Hugo confirmed the positive effect of the use of this technology in education and provided the opportunity to identify the use of augmented reality technology as one of the most promising means of increasing the efficiency of learning process in higher education institutions [2, 5, 13, 15, 18,

24, 27]. The works of O. Vysotskaya, K. Vyslyanskaya, N. Grinnyk, R. Kellan-Jones, O. Kostruba, V. Malynka, M. Nitki, and others are devoted to the technological tools that enable the introduction of augmented reality and virtual reality into the media environment [32]. At the same time V. Tsvetkov views virtual reality as a new form of representation and modeling of reality which gives an opportunity to gain new spatial knowledge. According to the scientist, virtual reality is a model-based multi-dimensional (3D) environment that is generated by computer means and responds realistically to the interaction with users [33]. Analyzing the latest innovative approaches and models of the use of augmented reality components in education, we should pay attention to S. Litvinova's research, aimed at the introduction of cognitive tasks using computer modeling as a determinant of increasing students' cognitive activity [11]. It is worth mentioning O. Pinchuk, V. Tkachenko, O. Burov's research, which is aimed at comparative analysis of the use of mobile applications as elements of creating cognitive tasks for students in the process of natural and mathematical disciplines learning [20]. In the framework of interdisciplinary research we have to take into account scientific analysis of the effectiveness of the use of search algorithms of learning based on cognitive visualization (L. Bilousova, L. Gryzun, N. Zhytienova, V. Pikalova) [1] and the experience of implementing an innovative approach while providing a support for pedagogical interventions in information technologies for education based on Bayesian networks (J. P. Martínez Bastida, E. Gavrilenko, A. Chukhray) [14]. Researchers (N. Balyk, O. Barna, G. Shmyger and V. Oleksiuk) have methodologically substantiated and empirically proved the effectiveness of implementing a model of teachers' professional retraining based on the development of STEM competencies [26]. In order to analyze the introduction of AR/VR technologies into the context of implementing a competency-based approach in the sphere of higher education, we have analyzed N. Morze and O. Glazunova's study on motivational component of the model of specialists' training, based on the analysis of modern standards of professional competencies of IT teachers. It consists of a series of stages: needs analysis for training; selection of training courses; completion of courses; assessment of professional competence level [8]. However, despite the deep analysis of the information given above, the mechanisms of using augmented reality in higher education, taking into account the individual characteristics of students, remain insufficiently studied, which led us to writing this article.

3 Research Methods

This research was conducted in the framework of joint research work of teachers and students (future psychologists and programmers) at the Laboratory of Psychophysiological Research and STEAM-Laboratory. The methods used in the process of research are the following: method of theoretical sources analysis; study of advanced psychological and pedagogical experience of foreign and domestic teachers on the issue of implementing a competency-based and person-oriented approach into the educational process in the sphere of higher education; development of soft-skills competencies in the process of future specialists' training; generalization and conceptualization to formulate the main points of the study; designing and modeling of empirical construct of combination of traditional and latest AR/VR technologies on the

example of diagnostics and development of future specialists' stress resistance; generalization and evaluation of results.

4 Research Results

4.1 Theoretical Foundations

According to the analysis of existing actual researches on the use of augmented reality in the process of identification and correction of personality's stress states, we have developed the concept of cooperation of two laboratories of Bohdan Khmelnytsky Melitopol State Pedagogical University - STEAM-Laboratory and Laboratory of Psycho-physiological Research. Interdisciplinary research was carried out within the framework of the implementation of research work, which is performed at the expense of the General Fund of the state budget: "Adaptive system for individualization and personalization of professional training of future specialists in blended learning" – the state registration number: 0120U101970. As a result of complex analysis of data, technical possibilities and close cooperation of teachers and students (future psychologists and programmers), a model of introduction of AR technologies in the process of development of future specialists' stress-resistance in the conditions of higher education has been designed.

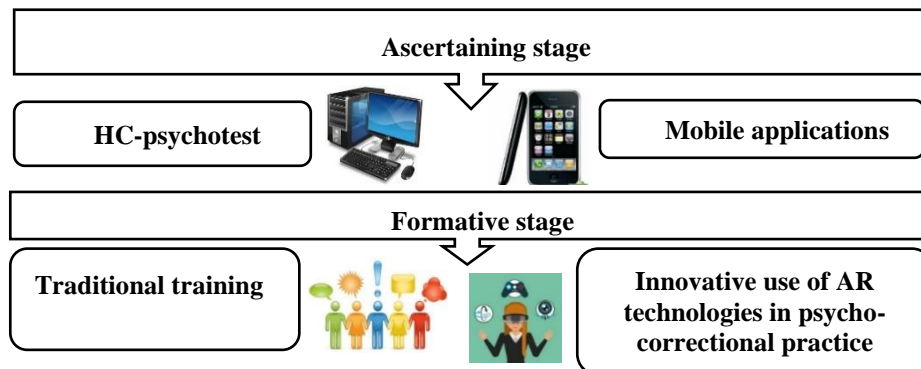


Fig. 1. Model of empirical study of future specialist's stress resistance development: experience of cooperation of STEAM-Laboratory and Laboratory of Psychophysiological Research

The pilot study consisted of ascertaining and formative stages. Total sample (randomized) - n=50 people (future programmers). According to the research objectives, the respondents were divided into control and experimental groups. No training sessions were conducted with respondents of control group. Specially organized corrective work was carried out with the respondents of the experimental group. Individual and group forms of training work were used within the limits of personality's stress resistance development. The training included elements of traditional psycho-correction work and components of AR technologies. The study was conducted during 2019 - early 2020. Students were actively involved in all stages of the study in order to enhance their scientific potential and motivation for the research. Let's consider each research stage in turn.

1. *Ascertaining stage*. Pilot psycho-diagnostic research was conducted at the Laboratory of Psychophysiological Research with the use of an innovative computer-based complex of HC-psychotest. To research the issues of future specialists' stress resistance diagnosis the following configurations of the HC-psychotest have been used:

a) Case "Candidate". An effective and easy-to-use tool for career guidance and selection of candidates for vacant positions, regardless of their work experience.

b) Case "Start" is used in screening psychophysiological research and gives an opportunity to monitor: features and states of personality; disorders of various mental functions; temperament and mental stability; interaction of personality and group.

At the diagnostic stage of the pilot study the following techniques have been used:

- In order to assess the formally dynamic characteristics of emotionality of people selected for the study, the questionnaire of temperament structure by V.M. Rusalov was used, in particular, the data of two scales: plasticity and emotional sensitivity.

- Qualitative characteristics of emotionality in the structure of personality have been assessed by means of Spielberger's Questionnaire in Hanin's modification (to identify situational anxiety and anxiety as a personal trait).

- Freiburg Personal Questionnaire (FPI, Form B) is designed to diagnose mental states and personal traits; it gives an idea of the effectiveness of social and professional adaptation processes, as well as of behavioral regulation.

In order to identify the level of self-analysis and self-control over stress resistance, the respondents were offered to use the following mobile applications [17]:

- Y&S personality scanners: psychological, diagnostic and psycho-emotional. The use of the appropriate application, first and foremost, is focused on self-diagnosis, which allows respondents to understand themselves better, to consider their inside problems, to self-improve in development, to make amendments in behavior and to have a confident behavior in society (<https://pfscanner.com/>).

- Psychology: tests - self-monitoring of mental and emotional states, identification of psychological personal traits (<https://play.google.com/store/apps/details?id=com.tellstory.psychologicaltests>).

- 40 psychological tests + IQ tests - diagnostics of emotional states of personality and cognitive processes, identification of interconnection (<https://play.google.com/store/apps/details?id=com.muraDev.psychotests>).

2. *Formative stage*. At the formative stage we integrated traditional psychological training on the use of cognitive-behavioral, relaxation and case-study techniques and the innovative opportunities of AR technologies. The formative stage was carried out on the basis of STEAM-Laboratory [10].

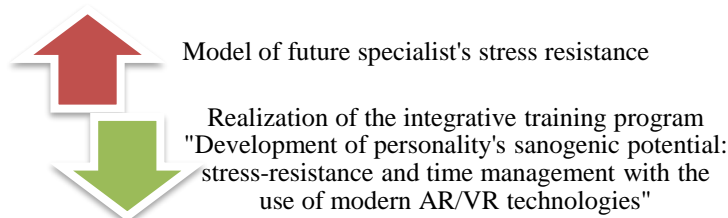


Fig. 2. Peculiarities of research formative stage realization

In this article we offer a model of future specialist's stress resistance, which shows the combination of future professional activity, individual personal traits, subject-activity level of personality, as well as personal level (see Fig. 3).

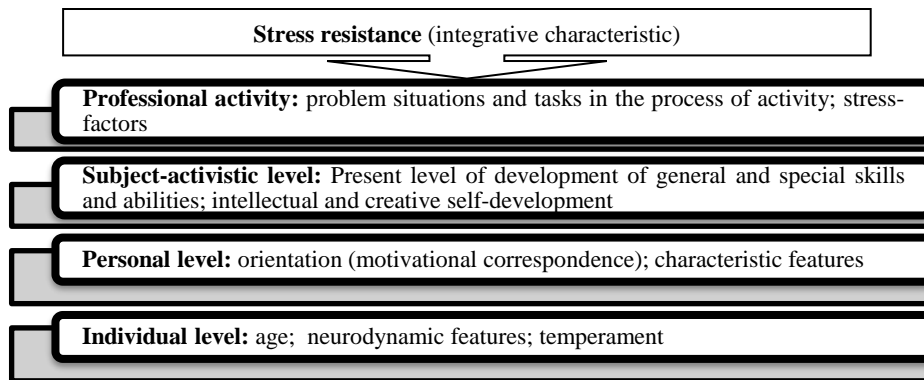


Fig. 3. Model of future specialist's stress resistance development

The structural-functional composition of the presented levels, on the one hand, is a quite stable component - according to the principle of systematicity and, on the other, it is a dynamic component, undergoing constant age and situational changes [12, 22]. The students analyzed the advantages of AR technologies in the process of their influence on the psychological features of the subject – environmental validity, control of the participant's attention in the virtual space, reducing the level of influence of side variables, possibility of selective isolation of the required stimulation, possibility of providing feedback in real-time environment, possibility to create a polymodal stimulation [34]. Traditional training, presented at the formative stage, included the psycho-corrective program "Development of personality's sanogenic potential: stress-resistance and time management" (see Fig. 4). The aim of the program is to increase the overall level of personality's stress resistance. Particular attention is paid to the formation of a positive image of a stressful situation, learning how to analyze the situation in a cognitive way, updating the skills of arbitrary relaxation and gaining the experience of applying techniques and formulas of constructive response in stressful situations [19, 23, 30, 31].

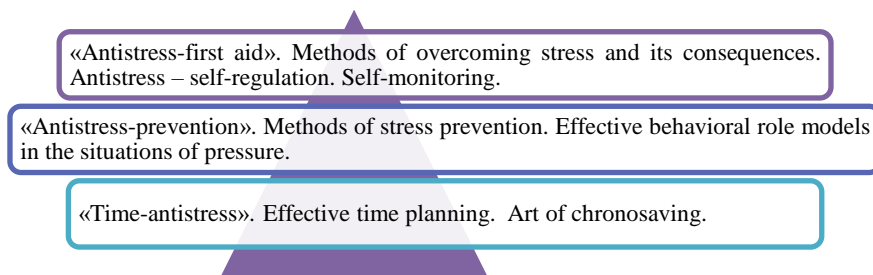


Fig. 4. Structure of the training program "Development of personality's sanogenic potential: stress-resistance and time management"

The program is created in accordance with the principles of the concept of Accelerated Learning Theory and uses all the latest developments in the field of methodology of adult learning. In order to implement the constructs of virtual and augmented reality we have used special technical equipment of STEAM-Laboratory. The minimum set of equipment, which is required to implement such an integrative approach is the following: required number of smartphones and VR helmets; tablet; computers; Wi-Fi router, Internet access; system of remote update; educational videos and software; touch pad. The XRcase system gives the opportunity to deliver classes on 10, 16 or 30 virtual reality devices. In the process of traditional training delivering, the elements of AR technologies were actively used [25, 29], namely:

1. While implementing the elements of cognitive-behavioral therapy, desensitization techniques, aimed at reducing anxiety (fear) to scary objects or situations (such as fear of flying, heights, fear of spiders, mice, snakes), the following Google Play applications were used:

- VR Thrills: Roller Coaster 360 (Cardboard Game). An amazing roller coaster adventure in virtual reality mode. This game provides the users with the opportunity to see many different types of roller coaster in virtual reality mode. It gives the chance to feel and reflect on various mental and emotional fears, maybe even frustration.

- VR Heights Phobia. A virtual reality game with a challenge! While completing the mission, participants cope with their phobias in the VR world. They use their own body to navigate the three-dimensional world, bounce their heads up and down, and the avatar moves as well. Each movement is monitored by a telephone gyroscope, giving participants a realistic, enjoyable experience, and the participants focus on and deal with their emotions.

- VR - Phobia Horror Spider. Through this program, participants try to overcome their arachnophobia. Students explore the world of spiders at 2 different levels and their environment. This virtual, but very close to reality case, develops the skills of self-control and emotional stability in extreme stressful environments.

- VR Maze. VR Ball Maze for cardboard and daydream virtual reality glasses. Participants need to roll the ball across the maze from start to exit. The ball always moves straight. The movement of the ball is controlled by the rotation of the head. This game is aimed at the development of concentration and stability of attention, emotional intelligence, and internal analysis of psychophysical states.

- VR Mission Leviathan – underwater expedition. Virtual reality attraction VR Mission Leviathan is a 360 VR adventure. A VR helmet, goggles, or cardboard allow participants to fully experience the depth of field explorer. Mission Leviathan's VR attraction is an underwater mission simulator. Surrealistic virtual reality with carefully crafted sound and detailed 3D graphics, clear, vivid and colorful models and characters, is aimed at a comprehensive impact on all sensory features of the person, at the same time arouses a variety of emotions, feelings and experiences, shapes cognitive-reflective skills of information processing and making decisions in difficult conditions.

2. In order to implement relaxation techniques using AR technologies, the following applications have been used [6]:

- Graffiti Paint VR. In Graffiti Paint VR participants spray Graffiti in virtual reality! They just choose a can or create their own one with a certain color and start to

spray it. This application provides the possibility of psycho-emotional relief, overcoming neuro-psychic tension.

- Art Therapy. Art Therapy is an application for adults that help users concentrate on positive emotions, create their own art masterpiece, relieve emotional tension and relax [15].

- ArtOlg: Introduction. A workshop of intuitive creativity for meditation is a kind of Art Therapy. This technique is very simple, anyone, who wants to open up their inner world, realizes hidden abilities, expand consciousness, can start drawing. Intuitive painting will help users get rid of the stereotypes of thinking that prevent them from living a common life and enjoying it. The main aim of manual art therapy is to harmonize the mental state of the individual through the development of the ability to express themselves through creativity.

- Thisissand - Art, Creativity & Relaxation. Thisissand is a creative space for designing objects from colored sand; it is focused on reducing psycho-emotional stress, situational and personal anxiety, as well as on the promotion of personality's creative potential;

- Relax River VR. Participants can achieve emotional and psychological comfort while having a virtual reality boat tour, sailing on a beautiful river, with picturesque scenery of mountainous area and incredible creatures. It is a fully automatic tour, without any settings.

1. The use of augmented reality components while implementing cognitive-behavioral therapy and self-reflection:

- Moodpath - Depression & Anxiety Test. Moodpath is focused on assessing mental health, monitoring and reflecting one's own mood, as well as taking a break from negative thoughts and negative emotions. Moodpath is used as an intelligent mood tracker. Through it, participants are provided with a chance to have a quick overview of their emotional states throughout the day, master cognitive-behavioral therapy (CBT) activities, understand the cause-and-effect relationship between events and emotional states, integrate mindfulness into their daily lives, develop empathy and skills of self-observation.

- CBT Companion: (Cognitive Behavioral Therapy app). It is the most comprehensive cognitive-behavioral therapy application available today. It is equipped with easy-to-use visual tools. The application presents the scheme of formation of certain skills through cognitive-behavioral therapy. A block of video lessons is also given.

- ACT iCoach: Acceptance Commitment Therapy App. ACT iCoach is a comprehensive application that covers all aspects of acceptance and commitment therapy. Participants learn and practice ACT skills using video tutorials and fun animation that help them learn more. The application provides participants with convenient tools for tracking their mood, emotions.

- CBT Thought Diary - Mood Tracker, Journal & Record. A central element of cognitive behavioral therapy (CBT) is training to identify negative and distorted patterns of thinking in order to change one's own emotions and behavior for the better. In cognitive-behavioral therapy, "record of thought" leads participants through the stages of detection, denial and rethinking of negative models of thinking. With the Thought Diary, participants can record their negative emotions, analyze the draw-

backs in their thinking, and re-evaluate their negative thoughts into more balanced ones.

The integration of traditional AR technologies is aimed at the formation of the following soft competencies:

1. Cognitive (intellectual) competencies: knowledge of stress signs and their interpretation, stress types and stages of development, impact of stress factors on personality's psychological well-being and on life as a whole.

2. Motivational competences: development of individual stress resistance and choice of effective individual program of organization of living space and time management.

3. Communicative competences: focus on the communicative situation (ability to choose verbal and non-verbal means of communication, based on the situation content, its participants, one's own attitude), development of constructive coping strategies of behavior in a conflict situation, enhancement of self-confidence, emotional competence in communication.

4. Social competencies: personality's ability to adjust to new social conditions, ability to constructively set a goal and find ways of its achievement.

5. Technological competences: ability to organize a workplace, ability to use methods of transformation [4].

4.2 Examples of Implementation

At the stage of ascertaining research it has been found out that:

- a majority of respondents (36%) showed a predominant tendency to monotonous work, fear and avoidance of various forms of behavior, absence of flexibility, conservative forms of activity;
- a majority of research participants (38%) have a high sensitivity to the differences between conceptualized and expected issues, planned actions and results of real actions, feelings of uncertainty, anxiety, inferiority, high level anxiety about work, sensitivity to failure;
- diagnosis of anxiety level showed that a majority of respondents have a high level of situational anxiety (44%) and a medium level of personal anxiety (38%). Respondents with a high-anxiety level tend to feel the threat to their self-confidence and vitality in a wide range of situations and to respond to these situations with a high level of anxiety. Very high level of anxiety can be directly linked to the presence of neurotic conflict, emotional breakdowns, and psychosomatic illnesses. Low level of anxiety, on the contrary, characterizes the state of a person as a depressive and inactive one, with a low level of motivation;
- a majority of students have high and medium levels of neuroticism (34%). In case of high neurotic indicator, as well as in case of the sensitive type of nervous system, the peculiarity of which is the reduction of threshold of intelligibility, the sensitivity level has increased. As a result, indifferent stimuli easily cause outbreaks of irritation and agitation. Usually, those features that are characterized by an increased level of excitability are also characterized by an increased rate of exhaustion and fatigue. Respondents with low and medium "neurotic" indicators are characterized by calmness, ease, emotional maturity, objectivity of self-evaluation and evaluation of other people, stability in plans and preferences. They do not reject their own short-

comings and blunders, they do not worry about small things, they feel well-adapted and show conformity;

- a majority of participants have a low level of emotional lability (40%). Low indicators are found out with emotionally mature individuals, who are not inclined to fantasies and think realistically. In their behavior, they are guided by reliable, truly tangible values.

Thus, the findings of the ascertaining research stage showed that a majority of the participants have low level of emotional stability and sanogenic potential in general. Respondents showed a high level of anxiety, restlessness combined with rapid exhaustion, low level of stress resistance, high anxiety about work, and sensitivity to failure. In order to finalize the results of integrative psycho-corrective work using the elements of traditional training in combination with modern AR technologies in the experimental group, a re-diagnosis was conducted so that to identify the dynamics of development of personality's stress resistance. To check the statistical validity of the data obtained before and after the correction, we used Wilcoxon's T-criterion.

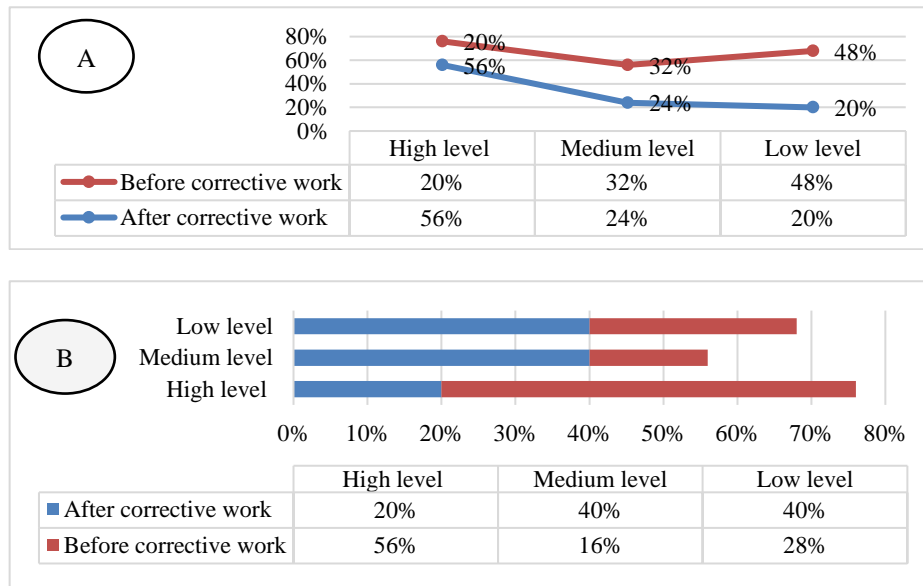


Fig. 5. Comparison of the results of the diagnosis of temperament structure according to V.M. Rusalov's indicators: a) "plasticity" b) "emotionality"

As a result of the comparison of empirical data after carrying out the corrective work on the basis of implementation of stress management program using the Wilcoxon T-criterion, it has been revealed that in the experimental group there is two times increase in the number of respondents according to the "plasticity" indicator (56%), there are no significant changes in the control group. Thus, we can conclude that after conducting psycho-corrective sessions, the indicators on the scale of "plasticity" have positively changed (compare $T_{emp.}$ ($T_{emp.} = 101.5$) with $T_{crit.}$, which at the significance level $p = 0.05$ and $n = 50$ is 466. We accept hypothesis H_1 : the signifi-

cance of the shifts in the typical direction exceeds the significance of the shifts in the non-standard direction). This indicates that the level of flexibility of thinking and behavior, ability to switch from one activity to another has increased. The indicators on the scale of "emotionality" have decreased, that is, there is an increase in the role of control over emotional manifestations while responding to different events related to practical activity and communication with people, the role of the cognitive component in the perception of stress factor (compare $T_{emp.}$ ($T_{emp.} = 101.5$) with $T_{crit.}$, which at the significance level $p = 0.05$ and $n = 50$ is 466. We accept hypothesis H_1 : the significance of the shifts in the typical direction exceeds the significance of the shifts in the non-standard direction). This indicates that the level of insecurity, anxiety, inferiority, anxiety about work, sensitivity to failure has decreased.

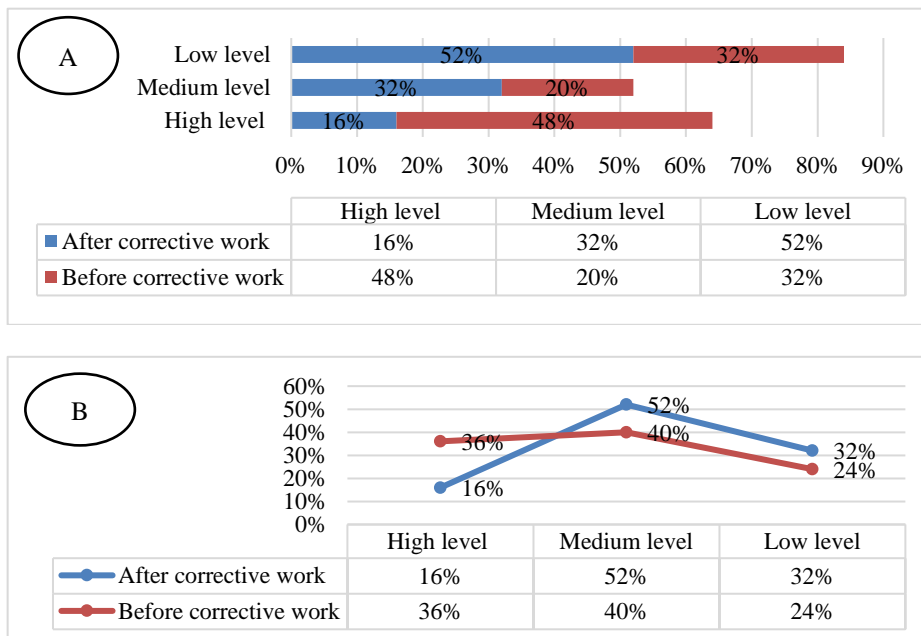


Fig. 6. Comparison of diagnostic results of a) situational and b) personal anxiety according to Spielberger-Hanin scale

After corrective work, the level of situational anxiety in the experimental group has decreased by 1.8 times (52% is the dominant low level). Compare $T_{emp.}$ ($T_{emp.} = 143$) with $T_{crit.}$, which at a significance level $p = 0.05$ and $n = 50$ is 466. We accept hypothesis H_1 : the significance of the shifts in the typical direction exceeds the significance of the shifts in the non-standard direction. This indicates that the level of situational anxiety has decreased. A decrease in the level of personal anxiety in the experimental group has been also found out and statistically proved, the dominant moderate level is 52%. Compare $T_{emp.}$ ($T_{emp.} = 120.5$) with $T_{crit.}$, which at a significance level $p = 0.05$ and $n = 50$ is 466. We accept hypothesis H_1 : the significance of the shifts in the typical direction exceeds the significance of the shifts in the non-standard direction.

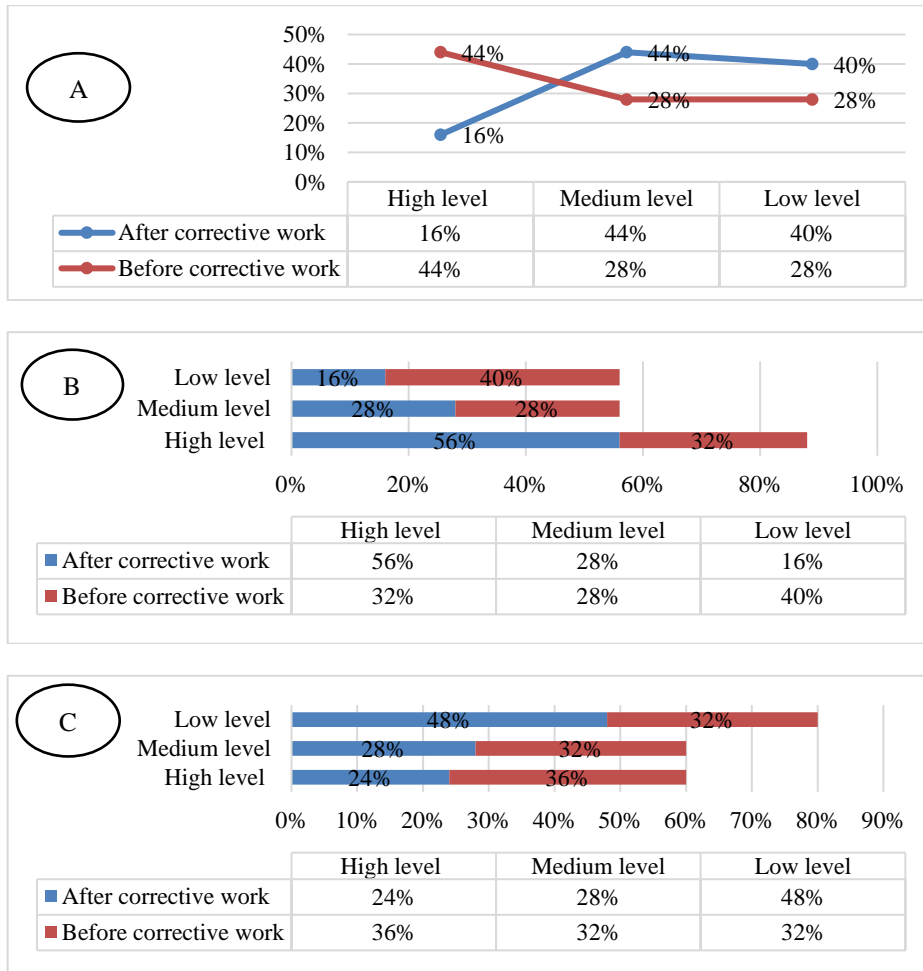


Fig. 7. Comparison of the diagnosis results of neuroticism level (A), equability of mind (B), emotional lability (C) by means of using a Freiburg Personal Questionnaire

As a result of the comparison of empirical data before and after corrective work it has been revealed that there exists a significant decrease in the level of neuroticism of the respondents (dominant average level - 44% and low level - 40%). Compare $T_{emp.}$ ($T_{emp.} = 111$) with $T_{crit.}$, which at a significance level $p = 0.05$ and $n = 50$ is 466. We accept hypothesis H_1 : the significance of the shifts in the typical direction exceeds the significance of the shifts in the non-standard direction. Thus, we can conclude that after conducting psycho-corrective sessions, indicators of "neuroticism" scale have positively changed. This proves the fact that the level of anxiety and agitation combined with rapid exhaustion has decreased. Scale VI (equability of mind) displays stress resistance. Most respondents have a positive dynamics in the development of equability of mind. A high level (56%) was found out to be dominant in the experimental group after the corrective work. Compare $T_{emp.}$ ($T_{emp.} = 140$) with $T_{crit.}$, which

at the significance level $p = 0.05$ and $n = 50$ is 466. We accept hypothesis H_1 : the significance of the shifts in the typical direction exceeds the significance of the shifts in the non-standard direction. After conducting psycho-corrective sessions, the indicators of the equability of mind scale have positively changed. It shows the increase of the level of freedom from conflicts, satisfaction with oneself and one's own successes, readiness to stick to the norms and meet the requirements. As a result of the implementation of training based on the use of AR technologies, the level of "emotional lability" of the experimental group respondents has decreased (dominant low level - 48%). Compare $T_{emp.}$ ($T_{emp.} = 182$) with $T_{crit.}$, which at a significance level $p = 0.05$ and $n = 50$ is 466. We accept hypothesis H_1 : the significance of the shifts in the typical direction exceeds the significance of the shifts in the non-standard direction. Thus, we can conclude that after conducting psycho-corrective sessions, the indicators on the scale of "emotional lability" have positively changed. This shows that the level of "emotional lability" has decreased. Analyzing the results, we can say that a psycho-corrective program with elements of AR technologies has contributed to the increase of emotional stability and stress resistance of the individual. It has been found out that future specialists' level of situational and personal anxiety, insecurity, inferiority, anxiety about work, sensitivity to failures has decreased. As for the level of flexibility of thinking and behavior, ability to switch from one type of activity to another, it has increased. So, a general level of personality's adaptive abilities has also increased.

5 Conclusions and Recommendations for Future Research

The key features of the system of future specialist's professional training are the results of globalization and technologization, which can be observed at the present stage of society development. Under the conditions of globalization, a network model of knowledge dissemination is being formed. It is characterized by the rapid dissemination of a new information product through the Internet [7]. In the context of the society technological development, new approaches and formats for the presentation and transfer of knowledge in the professional field are being formed. They provide available, high quality and personalized access; new conditions of professional activity realization due to the development of modern technologies (artificial intelligence, robotics, 3D modeling and prototyping, virtual reality, etc.). Analyzing the works of foreign authors on this topic (Kaiser R., Schatsky D., etc.), it should be noted that the increasing popularity of the augmented reality technology and interest to it, at the present moment, is driven by the research works that provide the rational for the prospects of using augmented reality technology through the expansion of production sphere and creation of completely new spheres and service markets in the near future [3, 9]. Due to such a global introduction of augmented reality elements into education, our research, aimed at the implementation of an integrative approach in the development of future specialist's stress-resistance, has turned out to be a very vital and important one. This research shows an innovative combination of traditional psychodiagnostic and corrective influences with modern AR/VR technologies. This research was conducted within the framework of the cooperation of two laboratories – Laboratory of Psycho physiological Research and STEAM-Laboratory. At the methodological level of the research we have analyzed and substantiated the ways of combining traditional methods with AR/VR technologies, and the model of personality's stress

resistance has been designed. At the empirical level, the effectiveness of implementing AR/VR technologies into the process of stress resistance development, as an integrative feature of future specialist, that directly influences productivity and efficiency of the future activity, has been proved. The perspectives for further research are the following: development of the concept of the purposeful use of AR/VR technologies while constructing an effective personality-oriented vector of higher education; research of the impact of augmented reality elements on a person's mental characteristics.

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Mobile Learning Approach as a Supplementary Approach in the Organization of the Studying Process in Educational Institutions

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Abstract. The traditional face-to-face educational attitude is now losing its positions to innovative ICT-style web-based approach. The problem of quality distance learning organizing is relevant for higher education institutions, especially nowadays with no borders not only for technology and information but also for physical viruses that make substantial corrections to the way people live, communicate and study.

Rapidly growing communication technologies put forward new requirements for future professionals in any sphere, this demand can be met by qualitative approach to learning techniques as well as significant educational process restructuring.

The article features different scientists' views on the notions of mobile (open, distance) learning, as well as blended (hybrid) learning. Foreign outlook on distance learning experience is given, domestic experts' research on the topic is analysed. The necessity of mobile learning approach implementation in higher education institutions is substantiated within the scope. It is supported by the results of a survey, completed by first and second year NTUU KPI students on specialties 122 (Computer Sciences) and 124 (System analysis).

It is emphasized that with the progress of a large number of web-oriented services, sophisticated technologies development, augmented and virtual realities implementation, new conditions are created for the development of learning skills to work with innovative systems. The article shows the need for the above-mentioned skills to be supported by a holistic system for distance learning organization in education institutions in Ukraine.

Keywords: distance learning, blended learning, mobile learning

1 Introduction

The ubiquitous use of technologies has significantly transformed the way people work, study, entertain and even the way they think and perceive information. With communication technologies development human brain begins to develop in a somehow different way, involving different parts of the brain, from what it takes to read a book and develop imagination to colorfully picture what is being discussed - to no need to imagine while watching a movie or using some 3D environment program where it's all done for us by actors or creators.

This inevitably changed the methods and ways teachers use for the organization of the educational process.

Everyday consumer electronic devices such as smartphones, laptops or tablets started to be used as pedagogical devices as well. With each piece of technology having slightly different presentation characteristics the teaching party aims at delivering best results.

The use of electronic devices (which were initially used only for communication or entertainment) into education brought such phenomenon as counter-interference between learning and different other processes, meaning that students organize their education at convenient time and place, quite often switching between other issues which they could be doing at the same time [1, p.16]. This, on the other hand, in some cases gives the effect of distraction from studying itself and possibly worsens the outcomes of the learning process.

Abdullah Saykili, from Anadolu University, Turkey, in his research for “8th Teaching & Education Conference” in Vienna in 2019 suggests that nowadays learners study with “a plethora of tools and applications that potentially interrupt the learning processes and distract learners from academic purposes” [2, p.325].

The question of bigger risks of distraction and easier dropout from the process of non face to face learning was also studied in the research “Understanding the Student Dropout in Distance Learning” done by Regina Barwald with a group of experts where they imply that early identification of students at risk of dropping out is possible due to predictive modeling analysis [3, p.2].

Notwithstanding the distractions or possible non-educational atmosphere and environment while doing studies with ICT, the new way of learning gains popularity. The following step is taking education out of the classroom into any students' convenient location. On this stage distance learning and blended learning were introduced as direct sequence of ICT development, and because of their convenience the above-mentioned learning types became rather popular among students.

2 Research methods

Pedagogical and methodical literature analysis, observation and survey as well as study on other researchers' works and conference contributions were used in the scope of our research. It is completed with the analysis of domestic and foreign experience of distance and blended learning implementation, an outlook on pros and cons of non-auditorium study, as well as the necessity of ICT use in the studying process organized by educational institutions.

An experiment was conducted to try out a project of blended learning implementation in English language classes. Observations over online studying organization were made during the distance learning implementation in the period of the quarantine in March 2020.

3 Research Results

The Learner Collection of “The International Journal of Technologies in Learning” in May 2014 puts education into a great value as a “space to re-imagine and try out a new and better world which delivers improved material, environmental and cultural outcomes for all”, which must “surely be a place of open possibilities, for personal growth, for social transformation“, where the educators are described as “forces of change” [4, p.10].

The authors imply that teachers as well as the whole process of educating both reflect the society with its interests, needs and changes, and nurture the kind of students who understand that they live in the community where individuals have a responsibility to interact in the world of overlapping social networks, which they determine and which they are determined by.

The authors use a name for this system of modern constructive studying - New Learning – obviously opposing it to the old ways of education. “While many nations persevere with educational structures founded in the 19th century or earlier, the knowledge economy demands different and creative approaches to learning” [4, p.10]. The above-described phrase corresponds to the general understanding of the idea of mobile (open, distance) or blended learning as well.

Distance learning, as a way of studying in which you do not attend any brick-and-mortar facility but are taught over the Internet, apparently took origin from correspondence courses, where the necessity to contact the teacher face to face gradually became less and less obvious with internet and cloud technologies progress.

In the book "Mobile and blended learning Innovations for improved learning outcomes" the beginning of online education is seen with BBC's free online courses in 2000 which were “supplemented by web-based resources”. It is presumed that rather than “the simplistic concept of anytime anywhere learning” the definition of such terms as “distance learning” and “mobile learning” was at its early start even more easily distinguished than it is now when the range of ICT devices and web-based technologies advance to more and more sophisticated levels, and distance learning involves gathering data, processing data, communicating, “interacting with interface”, “interacting with an outdoor environment” as well as the fact of possibility of “starting learning immediately” or “when it is required by the program” [1, p.17, 18].

Blended or “hybrid” learning is seen as the act of “mechanical blending” by Scientists at Clayton Christensen Institute (the USA) and is described as “a combination of the new, disruptive technology with the old technology” which “represents a sustaining innovation relative to the old technology”, and is actually a combination of old (traditional) teaching methods with the new ways brought by advanced technologies [5].

While blended learning, according to Parsons' and his colleagues' idea, bases on the combination of Distance, On site, Face-to-face and Online parts, where the key

component of context is seen as actual presence or non-presence in the brick-and-mortar classroom [1, p.19].

Teaching staff in Ukraine are now at the start of the distance or blended learning technology implementation, and researchers have only recently started analyzing it. Basing on the experience and works of their foreign colleagues they are developing a system of practical recommendations which can be applied in educational institutions of Ukraine.

In particular, S.L. Proskura thinks that Blended learning has high potential and it does not just reflect technologies and ways of learning, its main idea is seen by the researcher as personalization of learning [6].

Other Ukrainian experts - Yu.V. Trius, I.V. Herasymenko, see blended learning as a purposeful process of acquiring knowledge, skills and abilities, mastering the methods of cognitive activity on the basis of systematic use of both traditional and innovative pedagogical technologies in order to improve the quality of education [7, p.300].

The 2015 research of S.G. Lytvynova implies that the most widely used and result-giving Blended learning technique used by teachers in Ukraine at that time was the Flipped Classroom technique [8].

Distance Learning as well as Blended learning, both as ways of implementing newest IT trends constantly seek to “enrich learning experiences and processes by trying out innovative technologies and bring forward the best practices” [2, p.324].

Australasian Journal of Educational Technology published a research by Zeynep Kocoglu, Yesim Ozek and Yesim Kesli from Yeditepe University, Istanbul, Turkey, where they quoted Rita Kupetz and Birgit Ziegenmeyer from Hannover University, Germany, who indicated that the approach of blended learning uses activities designed to “support different aspects of student learning and to be flexible enough to respond to the needs of different types of learners” as well as “the integration of declarative and procedural knowledge, thus supporting the learner when constructing professional knowledge and skills.” [9, p.3].

Abdullah Saykili puts forward an idea that “educational practices undertaken in distance learning ... evolved into intelligent adaptive systems” which in recent years have “witnessed experimentations with innovative technologies such as Mobile learning, Gamification, ... Virtual reality and Augmented reality, ... which place learner in the centre of learning process, and all of this “enables considerable improvements in learner modeling and thereby personalization of learning processes.” [2, p.324].

The above-mentioned works of experts from different parts of the world support the idea that most of the innovations and refinements in both distance and blended learning have been developed to support a student-centered attitude which is now adopted in both state and private educational institutions in the whole world and in Ukraine in particular.

The authors are interested in studying and evaluating practical solutions of Distance and Blended learning implementation within the learning process in Ukrainian educational institutions as well as the amount of technologies that are presently used by teachers to organize the learning process in a sufficiently up-to-date way.

A survey on ICT use in the process of “in-auditorium” education was carried out by the authors aiming to evaluate the level of blended learning techniques which were used while organizing brick-and-mortar lessons at National University of Ukraine “Kyiv Polytechnic Institute” over the period of September-December 2019. Computer Sciences and Applied System Analysis specialties students were asked about the per-

centage of ICT use within the classroom activities they face in their lessons of programming and computer science at university. The graph below (Fig.1) features the following results: 24,3 % of all interviewed evaluate the quantity of technological presence in their technical subjects in-class lessons as only at 40% of capacity; at the same time 12,6% of the respondents see the full load of ICT use up to 100% which can not be considered as a step to the digitalization of the learning process provided by higher education institutions.

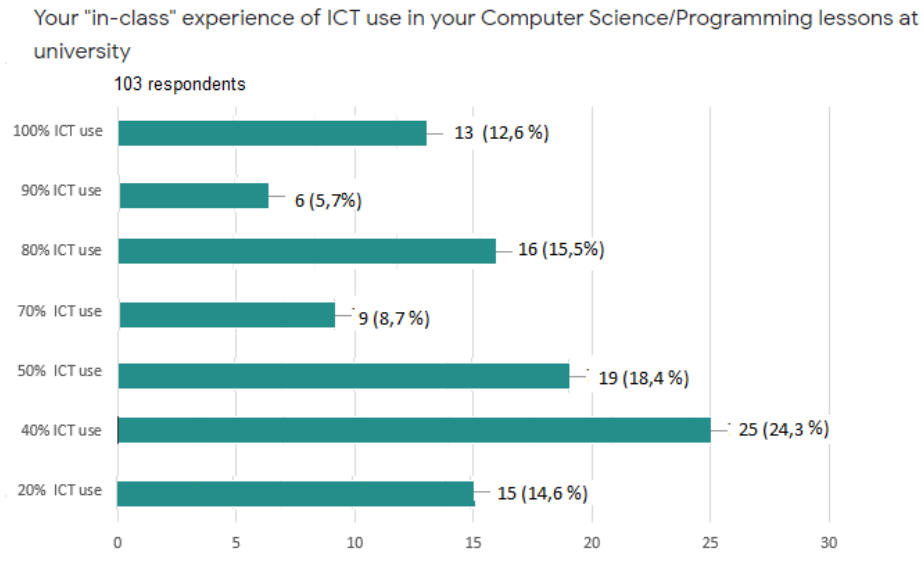


Fig. 1. Percentage of ICT use in technical discipline classes, students' evaluation

At the same time clear prevalence of technology use in technical subjects like programming or computer sciences over other disciplines (non-technical) can be seen in the responses of the focus group students (See Fig.2). The diagram shows poor 6,8 % of the respondents who think that ICTs are fully used in the classroom lesson, compared to 25,2% who think the technology is used only by 20% of capacity.

Your "in-class" experience of ICT use in other subjects lessons at university

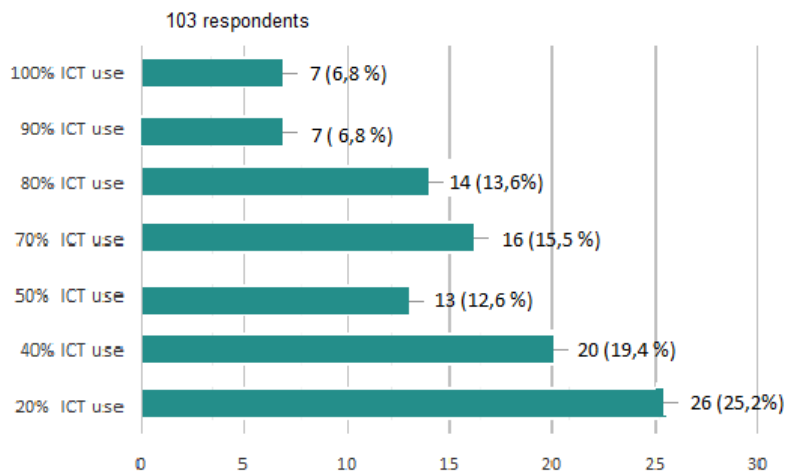


Fig. 2. Percentage of ICT use in non-technical discipline classes.

Modern technologies serve as basis while aiming at providing the best teaching and methodological support for students as well as for interactivity, assessment and feedback. ICT use is closely connected with the use of specific online resources which also raises the question of most fully appropriate as well as convenient for both teachers and students' use online platforms. Thus, S.L. Proskura in her work features such object-oriented learning environments as Moodle or Campus, as basis of the modern information and computer technologies in use [10, p. 5].

S.G. Lytvynova in her turn gives the ground for the use of cloud based technologies, proving that "There is a widespread adoption of cloud services ... They are the main tools for the efficient organization of cooperation and cooperative work between students and teachers now." [11, p. 3].

When asked about the platforms they use or are familiar with, the NTUU KPI students, participating in the survey, showed the tendencies, which can be applied to most technical specialties students at present period, although their experience is deeply affected by the teachers' or institutions' choices of platforms to deliver the knowledge on.

The graphs on Fig.3 show that 44,7% of the NTUU KPI students in Computer Sciences and Programming specialties have worked with Moodle, while 24,3 % find it not convenient to use, mainly because they consider it to be slow, as 1% of the respondents marked in comments.

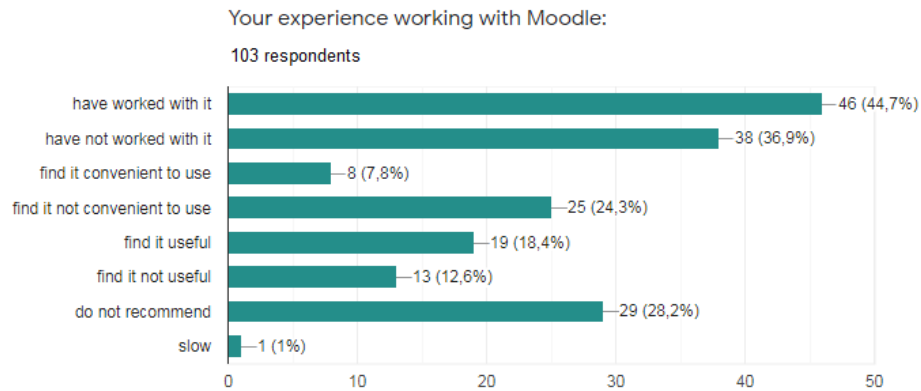


Fig. 3. Experience in working with Moodle

The second leading platform chosen by teachers to organize the learning process appears to be Google Classroom, as we can see in Fig.4, with 40% of the respondents having worked with it, and 28,2% finding it convenient to use, which is supported by the 43,7% of the students who see it as a really useful tool.

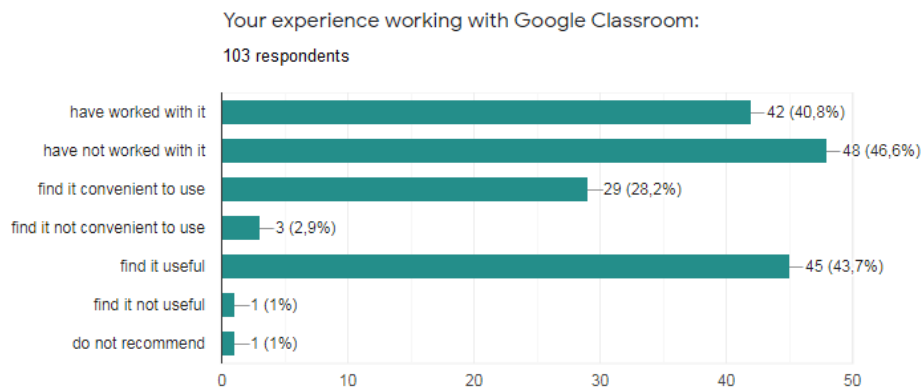


Fig. 4. Experience in working with Google Classroom

Another popular with students resource appears to be Quizlet.com, which organizes learning, revision and control in an amusing and even competitive way, providing online games and competitions. Fig.5 shows 38,8% of all respondents chose Quizlet.com as a supportive online platform, with 35% of students finding it useful, especially for language learning, and with 0% of non-recommending ones.

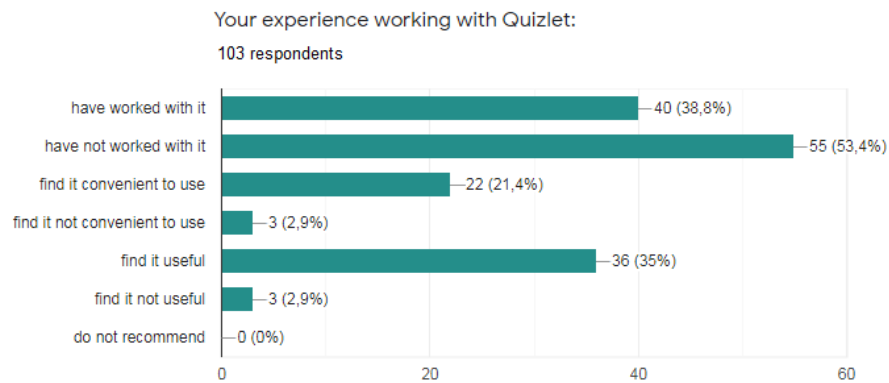


Fig. 5. Experience in working with Quizlet.com

Most evaluated stand-alone non-university platforms that are used in the role of supplementary tools are found as Coursera, Prometheus and Edx.org – see Fig.6, 7, 8 below.

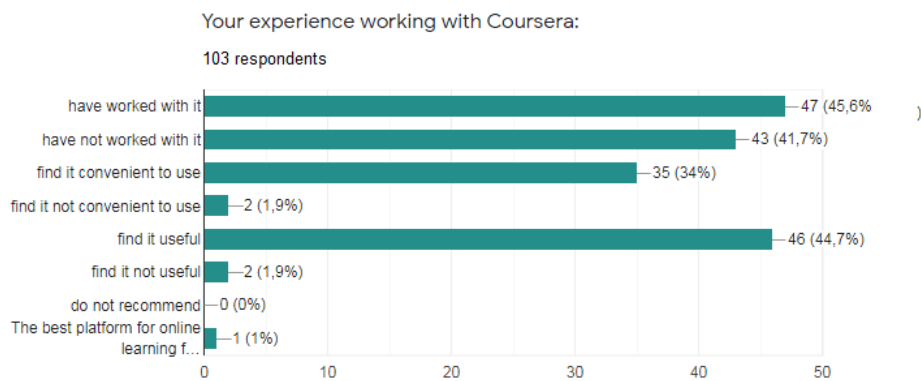


Fig. 6. Experience in working with Coursera

Coursera has been used by 45,6% of the respondents, and it has been considered useful by nearly the same amount of students (44,7%), with only 1,9% seeing it as not convenient or not useful.

Smaller amount of the NTUU KPI students who took part in the survey have experience in working with Prometheus. This is shown by the data introduced in Fig.7 which gives us the notion that 65% of the respondents have not worked with it compared to 27,2% of those who do have experience using it, as well as 25,2% of those who find it useful.

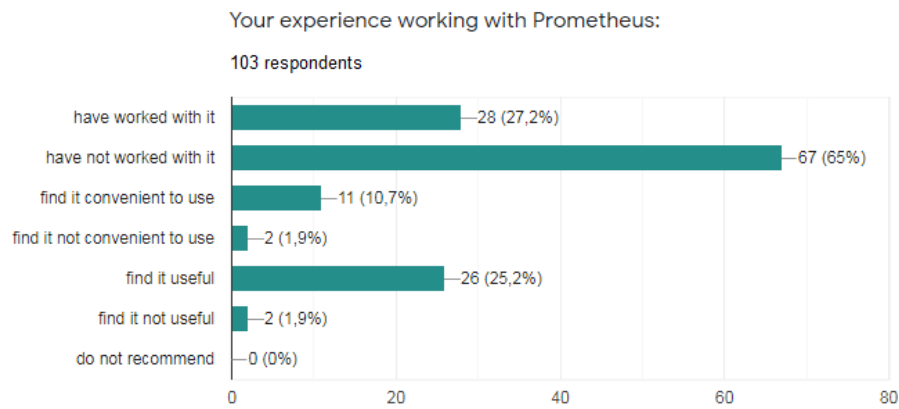


Fig. 7. Experience in working with Prometheus

Other platforms do not prove to be the same popular with the focus group students as the above-mentioned ones. The survey results analysis shows that 83,5% of the respondents are not familiar with Edx.org (Fig.8).

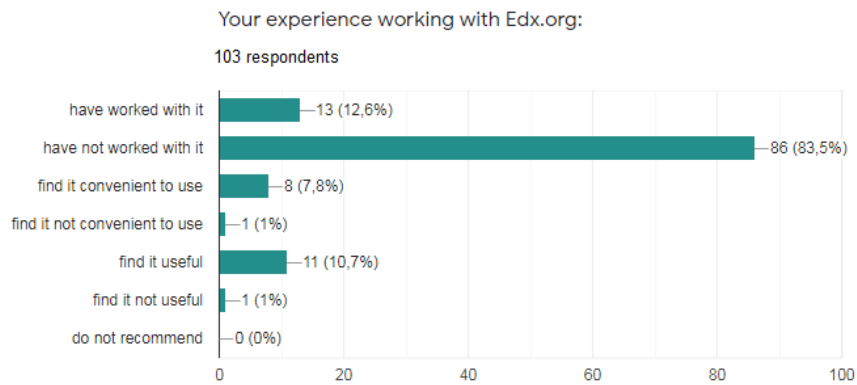


Fig. 8. Experience in working with Edx.org

In this respect platform CS50 from Harvard University takes 69,9% of all respondents who have no experience working with it, compared to only 22,3% who have used it for studying (See Fig.9).

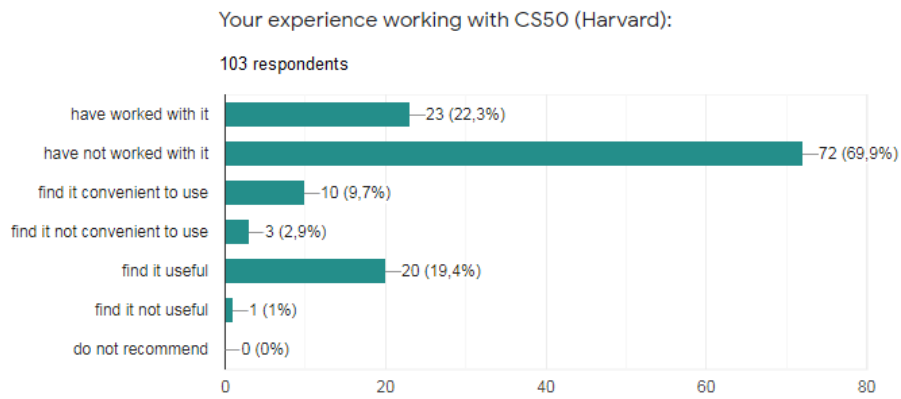


Fig. 9. Experience in working with CS50 (Harvard)

The above described survey of online platforms rating leaves such resources as Canvas, also known as Instructure, ITVDN and WizIQ out of the focus group's attention (See Fig.10, 11, 12).

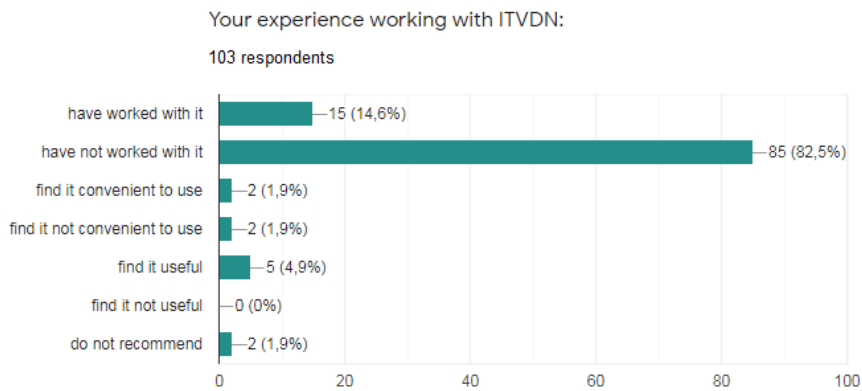


Fig. 10. Experience in working with ITVDN

Fig.11 shows only 14,6% of the respondents having worked with, where most of the focus group – 82,5% have no experience in working with it.

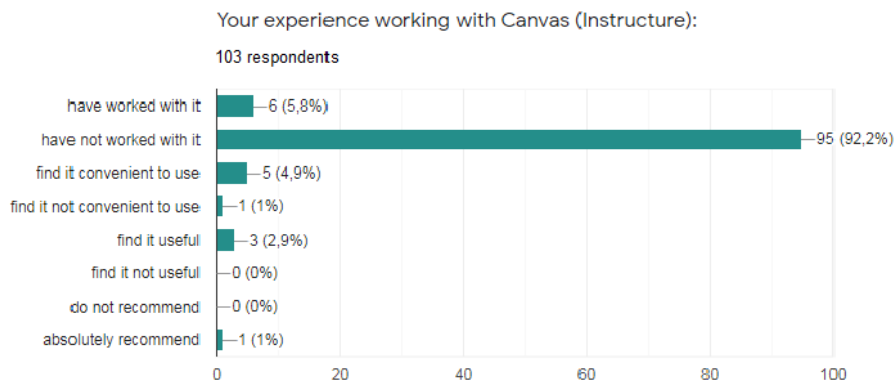


Fig. 11. Experience in working with Canvas

Canvas (or Instructure) can not be considered popular with NTUU KPI technical specialties students as well, leaving 92,2% of the respondents not familiar with it (Fig. 11). At the same time WizIQ seems to be the most undiscovered of all the above-mentioned online learning platforms, having a considerable amount of 96,1% of the survey participants unaware of its functions (Fig.12).

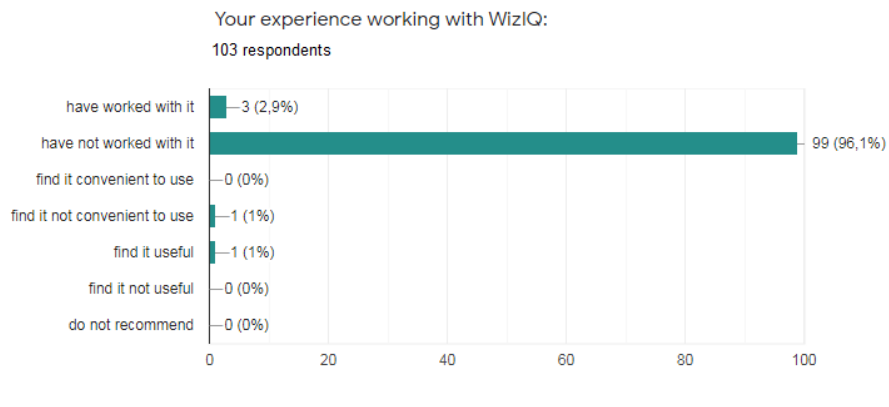


Fig. 12. Experience in working with WizIQ

One of main goals of the present study is to fully understand the juxtaposition between distance learning and ‘in-auditorium’ learning. Our research includes an observation on students’ attitude to the fully organized distance learning provided by the teachers of the NTUU KPI during the quarantine 2020 due to the prevention steps to stop spreading COVID-19.

Fig.13 shows clear preference of distance learning over classroom learning by the majority of the respondents, 27,5% see no advantages of it, though.

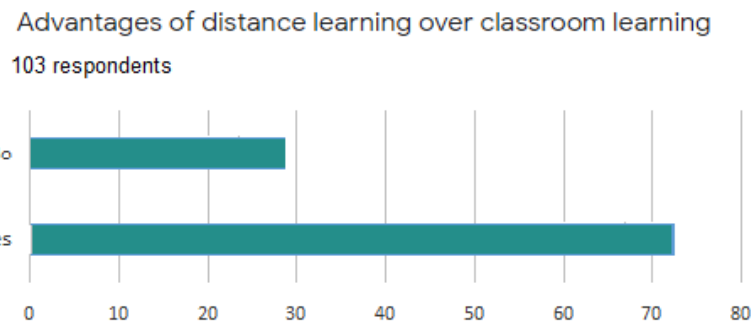


Fig. 13. Advantages of distance learning over “in-auditorium” learning

The authors do not have any intention to jump to the conclusion or to promptly follow modern trends, but a kind of tendency to subconsciously rate ICT-filled studying higher than the old ways traditional one can be traced. Understanding the substantial share of variations, attitudes and diversions each individual learner can bring to the process of student-centered education we studied the respondents’ descriptions of what the present fully distance learning process lacks to their opinion.

Fig.14 and Fig.15 illustrate some of the students’ answers, where they reveal some weak points which have to be improved.

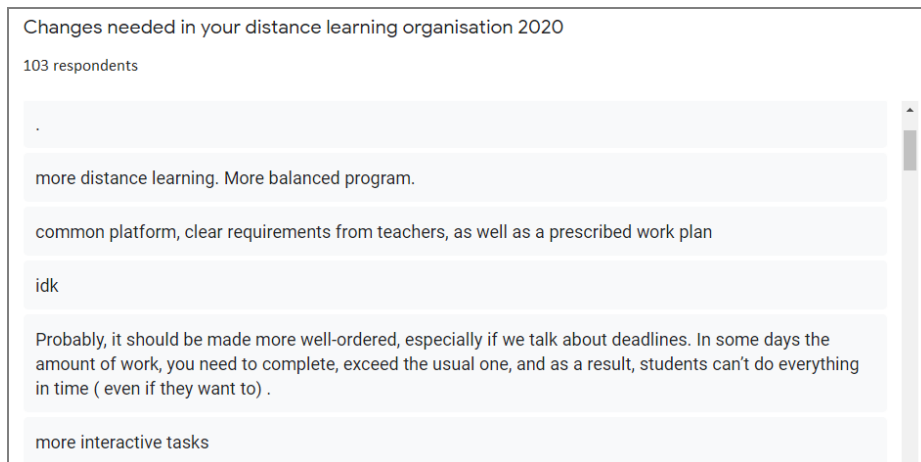


Fig. 14. Students’ views on the minuses of the distance learning organization provided in March - May 2020

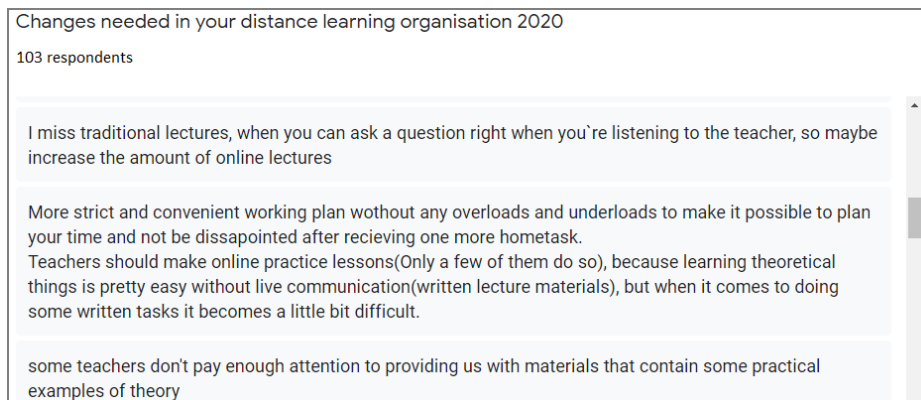


Fig. 15. Students' views on the minuses of the distance learning organization provided in March - May 2020 (part 2)

We can see from Fig.15 and Fig.16 that most inconveniences are caused by the absence of sequences of online video lectures on each subject, a more organized schedule with observed work load, as well as too few practical tasks completed with explanations or examples. Some of the other minuses include lack of common platform with clear requirements and too little interaction with the teacher, for example, video instructions or consultations.

4 Conclusions

It is obvious that times and technologies as well as minds and attitudes are changing drastically and the process of learning will no longer be the same as before. Every following generation will apparently be different, they will be people with different values, they will work, think, speak, process information, build communications in their own way. Even now standard training schemes tend to be ineffective for the new-coming generation. The world is changing so the approaches to learning have to be changed to keep up with the pace. It is the use of computer and web-based technologies supported by virtual and augmented reality (all of which can be called "mobile learning" as a general term) that can keep up with the developing demand on the market of educational services.

After studying and analyzing different types and models of learning with ICT implementation, considering the impact of rapidly changing internet communication technologies and observing the present global situation (when people are willing or have to and sometimes due to the circumstances are forced to stay in a particular place, keep to the rules of quarantine, dwell in the distance from their educational entity or even family and country) we can make a conclusion that the way of mobile learning direction can be adopted and developed as a supplementary line in educational institutions.

The results of the survey clearly showed that teachers in technical subjects like programming have been fully using technology for achieving best results. Non-technical subjects, on the other hand, are less supported by ICT within the curricula.

Students require additional supplementary learning to complete the harmonization of their education, so they seek for the help of online platforms which they lack provided by the university [12, p.6]. This fact is clearly visible from the responses of the focus group NTUU KPI students of technical specialties 122 (Computer Sciences) and 124 (System analysis) who took part in the survey done by the authors.

The survey results also show that online platforms such as Coursera and Prometheus are most widely chosen by the students to catch up with learning materials and programs, when other popular abroad resources, such as CS50 (Harvard) or Instructure have not gained popularity among Ukrainian students yet.

Educational systems in most general types of Ukrainian higher education institutions aim at in-auditorium studying process organization more than at mobile (distance) learning system development [13], [14], [15]. Present state and prospects of technology development, migration, remote working as well as global situation put forward the necessity of having methodologically supported program as well as technical and personnel capacity to fulfill sustainable distance education.

Evidence shows that students on their side see fully provided distance learning as a sufficient, interesting and more modern and way of knowledge obtaining. They find the experience useful. Some of their feedback ideas on the drawbacks of the present way of mobile learning organization which they have now can possibly be considered and adopted by institutions' guidance.

Thus we can suggest that further study of the question is needed as there appears a need to rethink and restructure the whole educational process, update the contents of educational programs and develop new holistic programs for distance studying to supplement mobile learning vector in education, to enrich students' involvement and concern as well as to avoid distraction and loss of interest. More research has to be done in the question of students' feedback and wishes about distance education improvements as they are the objects of educational activity who have to experience it in its only development phase.

This puts quite more responsibility on the teaching party, giving the teacher more work load. As learning technologies are changing rapidly and significantly teachers have to keep up with innovation, devote a lot of time for preparing appropriate involving materials to provide best possible learning outcomes. Which seems to also be really important is that the strategy of mobile learning vector has to be supported and developed on the institutional level.

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Using Massive Open Online Courses in Teaching the Subject "Computer Networks" to the Future IT Specialists

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Abstract. The article presents the experience of using massive open online courses in the training of the discipline "Computer Networks" of future IT specialists. The content of the study of the discipline "Computer Networks" in different institutions of higher education in Ukraine is analyzed. It is noted that in the study of this discipline at the Zhytomyr Polytechnic State University to work independently through the platform of massive open online courses Cisco Networking Academy material of the integrated training course CCNA Routing and Switching. The description of the possibilities of using mass open online courses in the training of discipline "Computer Networks" of future IT specialists. The expediency of the use of mass open online courses in teaching the discipline of "Computer Networks" of future IT specialists through the pedagogical experiment, the results of which proved the feasibility of introducing these courses in the educational process of higher education.

Keywords: massive open online courses, computer networks, IT professionals.

1 Introduction

1.1 Formulation of the Problem.

In the process of professional training of students of all specialties 121, 122, 123, 124, 125, 126 industry 12 "Information Technology" binding study is discipline "Computer Networks". Analysis of the curricula of higher education institutions Ukraine (Zhytomyr Polytechnic State University, National University of Life and Environmental Sciences of Ukraine, Ternopil Ivan Puluj National Technical University, National Technical University of Ukraine "Igor Sikorsky Kyiv Polytechnic Institute", Taras

Shevchenko National University of Kyiv) showed that the study of subjects given 120 to 270 hours.

It determines the need to use platforms of massive open online courses (MOOC) in higher education institutions (HEI). Platforms MOOC usually contains traditional materials for learning (video lectures, text materials for self-study and related control tasks), but sometimes contain various additional features. For example, the ability to create a forum (chat) for registered users, where students can communicate and receive a variety of answers to their questions, not only from teachers but also from other MOOC users [1; 2].

1.2 Analysis of Recent Research and Publications.

Many scientists are exploring the problem of training IT professionals. In particular, T.V. Bodnenko, O.G. Glazunova, M.I. Zhaldak, V.V. Eremeev, O.V. Kharchenko, N.V. Morse, V.V. Osadchyi, O.M. Spirin, S.O. Semerikov, T.V. Voloshyna, and others.

In particular, V. Osadchyi conducted an analysis of the content and organization of training of specialists in software engineering at US universities [3], T.V. Bodnenko and O.V. Kharchenko investigated the problem of using cloud technologies in the process of training computer engineer [4], T.V. Voloshina developed a technique for using a hybrid cloud-oriented learning environment for the formation of self-educational competence of future IT specialists [5], O.G. Glazunova and O.V. Yakobchuk investigated the issues of architecture design cloud-based information and educational environment for training future professionals [6].

O.G. Glazunova also developed a methodological system for the application of an e-learning system for future specialists in information technologies in universities of agricultural profile [7]. L.F. Panchenko and N.A. Lavrynenko highlighted the problems of using multiagent systems in the training of future IT specialists [8], A.M. Striuk and M.I. Striuk consider methodical aspects of the use of cloud-oriented tools in the training of information specialists technologies [9].

Other researchers (N. Avshenyuk [10], N. Berezan [10], N. Bidiuk [10], M. Childs [11], G. Conole [11], M. Haenlein [12], A. Inamorato dos Santos [11], A.M. Kaplan [12], M. Leshchenko [10], B. Nkuyubwatsi [11], Y. Punie [11], A. Tannhäuser [11], G. Witthaus [11]) are exploring various aspects of the use of massive open online courses in higher education institutions

However, the use of platforms open massive online courses during their training today needs further examination.

2 Results

The purpose of the Computer Networking course is to give students the knowledge of:

- Principles and standards for the construction and operation of computer networks;
 - Local and global computer network technologies;
 - Information exchange protocols used on computer networks;
- and develop students' skills:

- Analysis of hardware and software solutions of computer networks;
- Practical skills in designing, implementing, operating computer networks;
- installing, debugging and administering network software.

The tasks of studying the discipline "Computer Networks" are: studying the general principles and standards of building computer networks, technologies of local computer networks, TCP / IP stack protocols, routing in IP networks, technologies of global networks and access networks, network operating systems and network software.

Here is an indicative subject of study of this discipline:

Topic 1. Introduction. Basic definitions and standards for computer networks.

Topic 2. Topologies, data channels, data networks on computer networks.

Topic 3. Computer Networking Models. OSI reference model.

Topic 4. Basic LAN technologies.

Topic 5. Modern high-speed local area network technologies.

Topic 6. Building computer networks based on hubs, bridges, and switches.

Topic 7. TCP / IP stack. Basic protocols.

Topic 8. Routing in IP Networks.

Topic 9. Technologies for support, global and access networks.

When studying this discipline at the Zhytomyr Polytechnic State University, students are taught to work on the CCNA Routing and Switching Integrated Training Course through Cisco Networking Academy Massive Open Online Courses [13], which consisting of separate smaller courses, namely: CCNA Routing and Switching: Introduction to Networks, CCNA Routing and Switching: Essentials, CCNA Routing and Switching: Scaling Networks, CCNA Routing, and Switching: Connecting Networks. The CCNA Routing and Switching course provides online training, test work, and test intermediate assessments.

In the course of studying CCNA Routing and Switching courses, Cisco Academy offers the following study material:

CCNA R&S: Introduction to Networks. The purpose of this course is to be acquainted with the basic concepts and technologies of networks. This knowledge can be immediately applied to the configuration of switches and routers. This course details the principles, models, technologies, and protocols of networking, including how Ethernet devices work the basic TCP / IP stack protocols.

CCNA R&S: Essentials. This course describes the architecture, components, and features of routers and switches on small networks. The course will provide you with the skills to set up and troubleshoot networking equipment, as well as common problems with RIPv1, RIPv2, OSPF dynamic routing, VLANs, and VLAN routing on IPv4 and IPv6 networks. This course also examines the work of DHCP and NAT technology.

CCNA R&S: Scaling Networks. This course focuses on the architecture, components, and functions of networking equipment on larger and more complex networks. The course aims to gain practical skills in configuring and troubleshooting routers and switches with advanced features, namely to solve common problems with OSPF, EIGRP routing protocols in IPv4 and IPv6 networks. Besides, the course develops knowledge and skills to implement wireless LAN in small and medium-sized net-

works.

CCNA R&S: Connecting Networks. This course discusses WAN and network services required by converged applications in complex networks. The choice of network equipment and WAN technologies to meet network requirements is discussed. This course also allows you to develop the skills needed to deploy VPN into complex networks.

Initially, courses offered by the Cisco Academy are created in English and only then translated into other languages. As a rule, a community of trainers does translation and localization of the course. Localized (translated) courses are due one month to one year after a new course or a new version of the course is available. Some courses, often professional-level courses, do not translate at all. The Cisco Ukrainian Academy of Instructors community is working intensively to translate the latest English language courses into Ukrainian. At the end of 2019, there are four such courses. At least four more courses related to network technology and cybersecurity are planned to be translated in 2020.

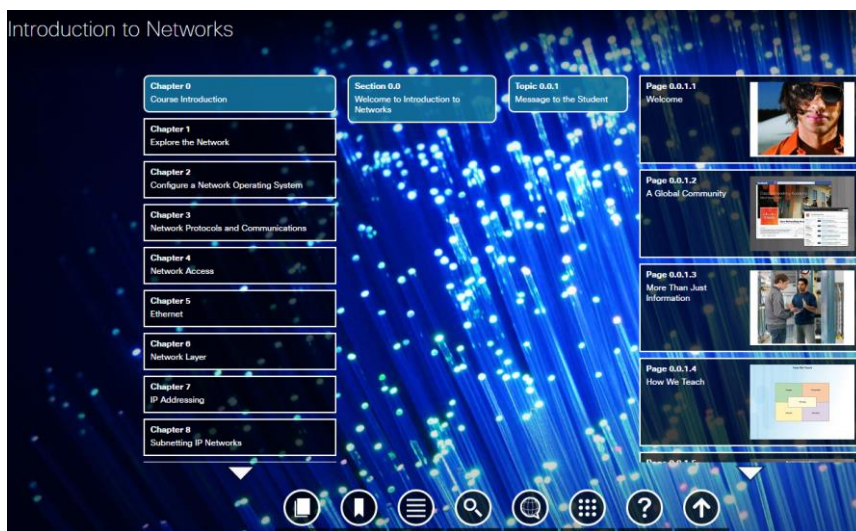


Fig. 1. Example system interface (course CCNA Routing and Switching: Introduction to Networks)

Let us look at some of the technical aspects of the Cisco Academy training courses. Cisco Academy is hosted on a cloud-based Netacad (Netacad.com) platform (an Amazon AWS cloud provider). The following courses are available at the Academy: self-led, self-led, and instructor-led. However, three levels of complexity are most common: beginner - for beginners (often open), Intermediate and Advanced - professional levels (usually closed or paid). Training facilities are available for educational institutions: 1) Cisco Academy - Student Learning, 2) Cisco ITC (Cisco Instructor Training Center), 3) Cisco ASC (Cisco Academy Support Center) - Cisco Academic Support Center.

Note that the Zhytomyr Polytechnic State University and Cisco have an agreement

on cooperation in student learning (cooperation began since 2000), and in September 2019, the University of Cisco Instructor Training Center and the Cisco Academy Support Center opened at the University. It is worth noting that not only universities, but also schools, colleges, and other institutions around the world collaborate with Cisco Academies.

So, for the self-study course "Computer network" Students are encouraged to go through four courses Academy Cisco. Let's take a look at one of these to get a closer look at the discipline of Cisco Academy.

Note that the Cisco Academy platform is adaptive across devices and systems, so users can access the learning environment through their account from any device (smartphone, tablet, laptop or PC). However, some of the specialized training programs or multimedia tools you need (for example, Packet Tracer network simulators, some tests, and some exams) are complex and resource-intensive, so you should use a laptop or PC to work with them.

The NetAcad environment is responsible for the interaction of instructor-trainers and students (students). The course materials include theoretical material (lectures in conjunction with graphic materials, video materials, game training cards for mastering the basic concepts of the topic) and performance materials (laboratory work, Packet Tracer work, tests and exams for each topic, as well as the final exam).

When educating future IT professionals, combining traditional approaches to blended learning with Cisco Academy allows you to apply a personalized approach to the learning process, increase student interest and motivation, and build student-teacher interaction.

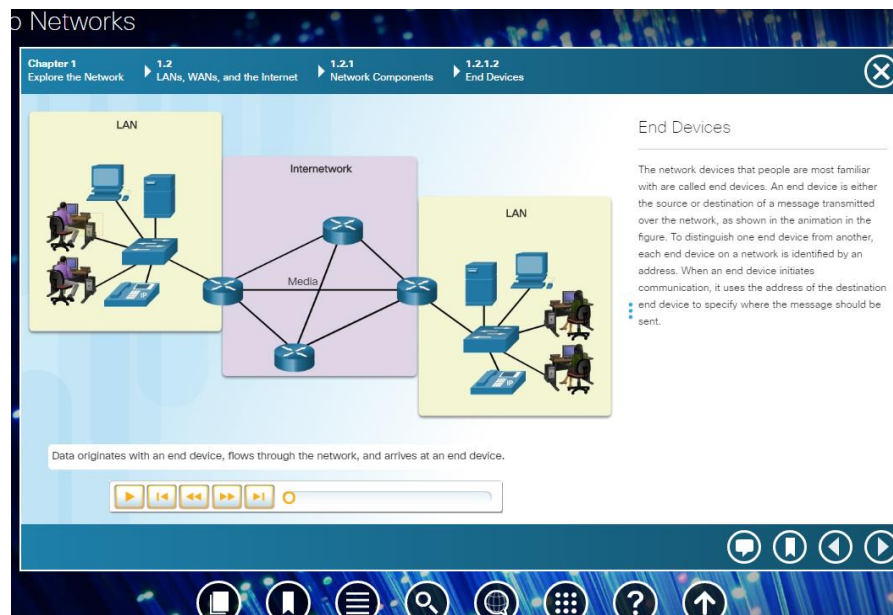


Fig. 2. Theoretical material

To begin with, students are encouraged to familiarize themselves with the theoreti-

cal background of the chosen topic. The theoretical material is accompanied by graphic and video materials (see Fig. 2–3). Note that the video material can also be viewed in text format (see Fig. 3).

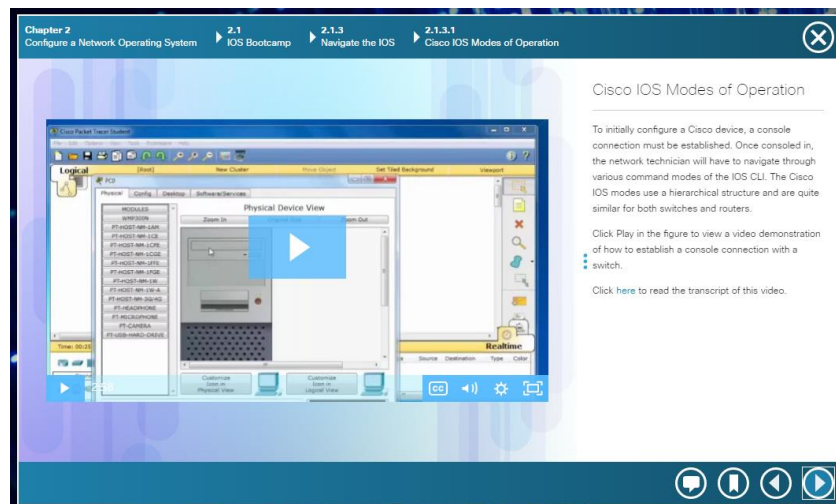


Fig. 3. Theoretical material (in the form of video material).

It should be noted that all the material is structured, and according to each topic, there are different types of submitting material and testing the knowledge (see Fig. 4).

With the help of the course pointer you can view the general list of materials, the list of works in Packet Tracer, the list of laboratory works, and the list of video materials (see Fig. 4).

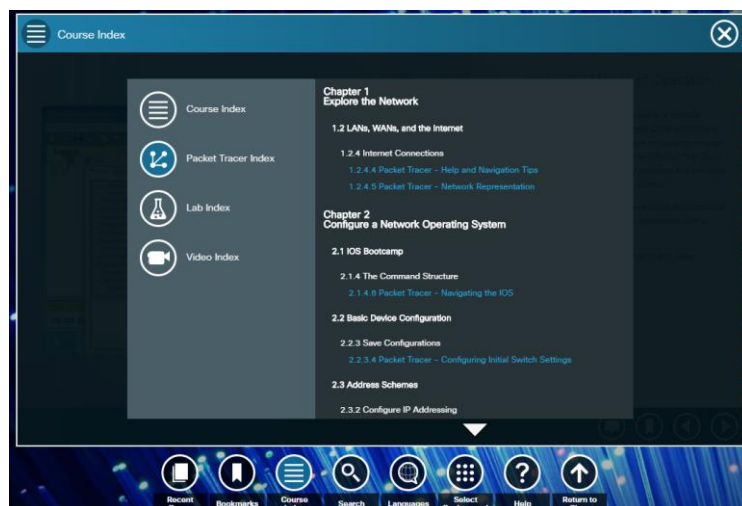


Fig. 4. Types of work

To perform the test and exam work, to view your grades, you must select the menu

"Back to class" (see Fig. 5).



Fig. 5. Course navigation

On the home page (home) of the course, you can choose course start (includes passing of theoretical material, video lectures, laboratory work, as well as work in Packet Tracer), tasks (includes all intermediate and final exams), tests (list of tests course work), assessments, etc. (see Fig. 6).

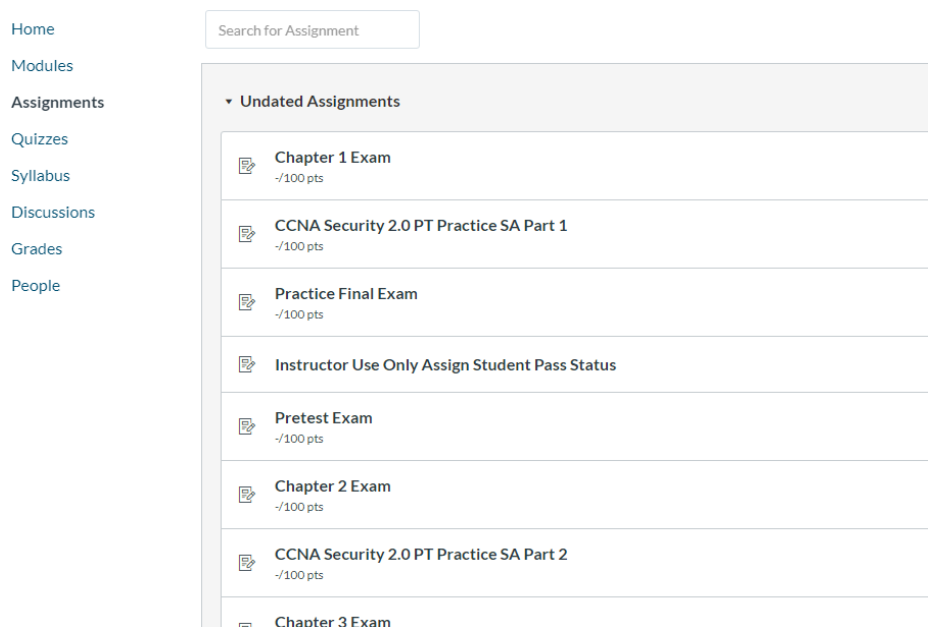


Fig. 6. Course page

Each test work is instructed to complete the test, indicating the time, the maximum score, the number of questions, limiting time and trying (see Fig. 7).

All tests are performed as tests. In this case, the assessment for the control work in the evaluation log is not submitted. This is just your preparation for the exam work on the topic as a whole.

After completing the test work, the system will provide the user with a complete description of the work completed (evaluation, correct answers, etc.).

You can review all the attempts and retake the test.

As a result, the journal estimates will be recorded only assessment of all examinations. This is a bit inconvenient for students as they are accustomed to traditional training when grades for tests are taken into account and only one exam is taken at the

end of the course.

Part 1 Summary Test

This assignment is part of the module **PART 1: BASICS** and hasn't been unlocked yet.

Completion Prerequisites

The following requirements need to be completed before this page will be unlocked:

Welcome to Python Essentials

[Terms and Conditions](#) [ACCEPT TO START THE COURSE]

must submit the assignment

[Welcome Survey](#) [SUBMIT TO START THE COURSE]

must submit the assignment

◀ Previous

Next ▶

Fig. 7. Instructions for control work.

Therefore, we consider it necessary, at the beginning of the course, to warn students about the specifics of this platform and to explain that the test work is only a training exercise, and the grades that are taken into account are the grades for all exams.

The advantage of this approach to learning is the acquisition of the subject through practical experience, using different types of practical work. To do this, students have the opportunity to see examples of solutions (the used text and multimedia); try to apply this knowledge in practice (using syntax checking tools); execute part of the example (using Packet Tracer or real equipment); and, finally, finding a solution to the problem (applying all the knowledge gained and using the tools available).

Note that Packet Tracer - a tool for visual simulation, developed by Cisco Systems, which allows users to create network topology and simulate modern computer networks. This software includes a wide range of physical and logical modeling systems (see Fig. 8).

The variant exercises with the use of this software include modeling networks, games, exercises, and more complex tasks, enabling end variants to gain practical experience working with computer networks.

Using Packet Tracer, students can create their experiments on computer networks. This is an opportunity to explore the particular job designed network protocol TCP / IP.

With this program have the opportunity to compete with each other participants and the whole team from performing certain types of tasks.

Using complex material and exercises proposed Academy Cisco, facilitates self-study materials to students, increases their interest in using vivid visualization of the entire material and game simulations in software tools Packet Tracer.

The use of these courses provides 100% coverage of topics prescribed curriculum study subjects.

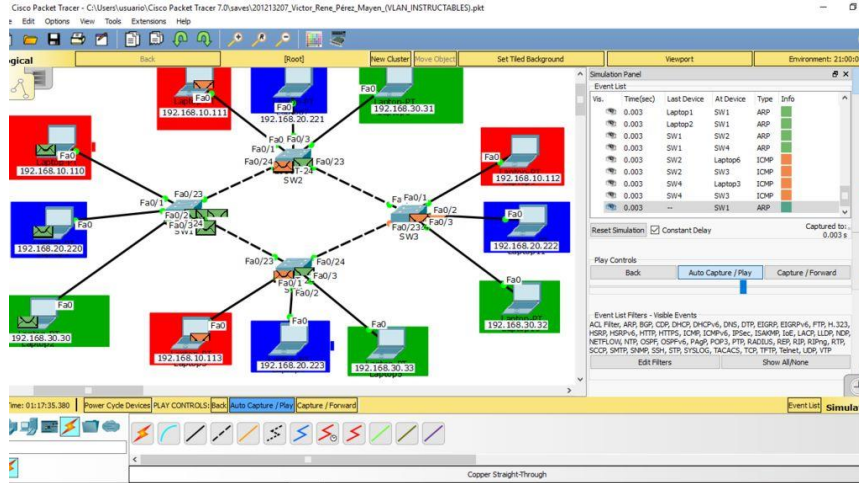


Fig. 8. Packet Tracer

Note that the Academy offers instructors a statistic (see. Fig. 9-11), where you can see the dynamics study courses on various parameters.

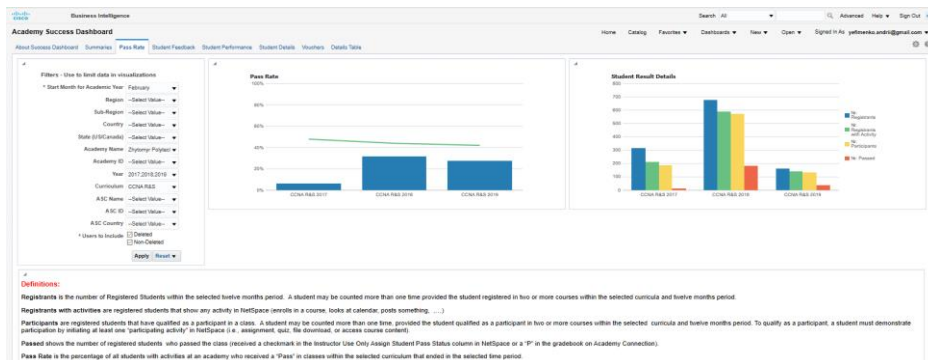


Fig. 9. Statistical Images of Course Studies at Cisco Academy

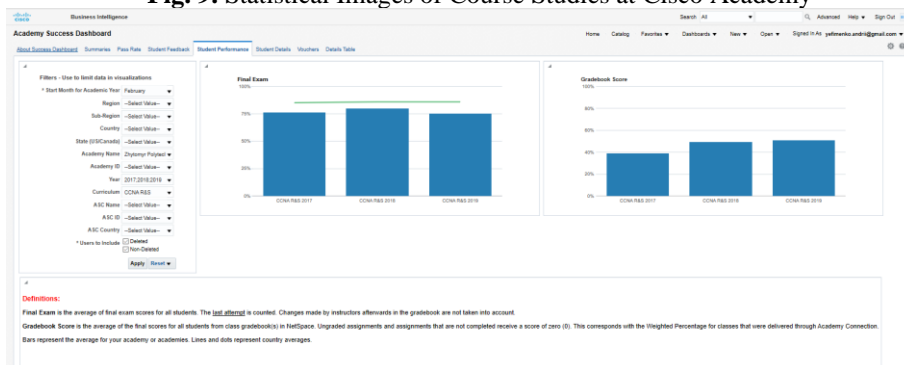


Fig. 10. Statistical Images of Course Studies at Cisco Academy

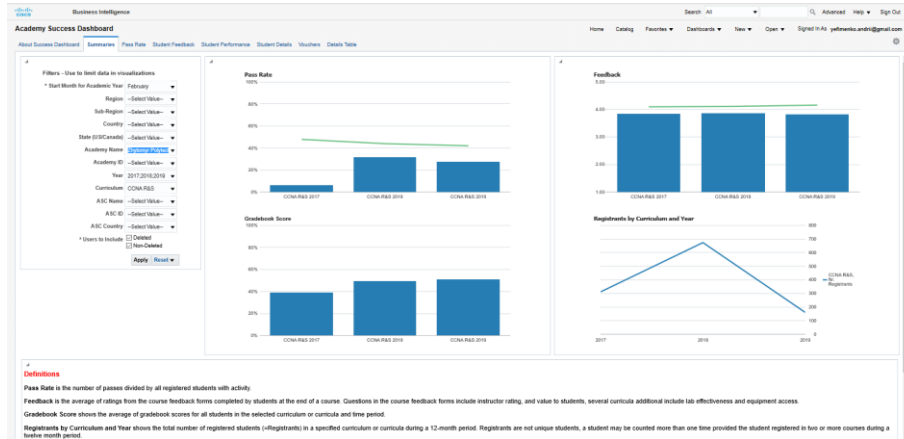


Fig. 11. Statistical Images of Course Studies at Cisco Academy

3 Discussion

To test the effectiveness of the implementation of courses Cisco Academy in the educational process of higher education, the pedagogical experiment was conducted at the Zhytomyr Polytechnic State University.

To do this, we measured the level of academic achievement of students by examining the discipline of "Computer Networks" at the beginning and end of the pedagogical experiment.

For this purpose, students were divided into experimental and control groups (EG and CG, respectively). At the same time, computer networking courses at EG were conducted using Cisco Academy courses and at CG at the usual methodology.

Table 1 and Fig. 12 show comparative statistics before and after the EG and CG experiments, respectively.

Table 1. Comparative distribution of CG and EG students by level of academic achievement at the beginning and end of a pedagogical experiment

Level of academic achievement	Before		After	
	CG	EG	CG	EG
Initial (1-59)	7	8	6	5
Average (60-73)	22	24	18	6
Sufficient (74-89)	18	16	21	30
High (90-100)	6	5	8	12
Total	53	53	53	53

At the beginning of the pedagogical experiment, Pearson's χ^2 test was used to check the statistical equivalence of EG and CG, which revealed that the samples had no

statistically significant differences (since $\chi^2_{\text{emp}}=0,36$, $\chi^2_{\text{emp}} < \chi^2_{0,05}$). Therefore, it is possible to say about equal conditions in EG and KG, as well as about the equal composition of their participants.

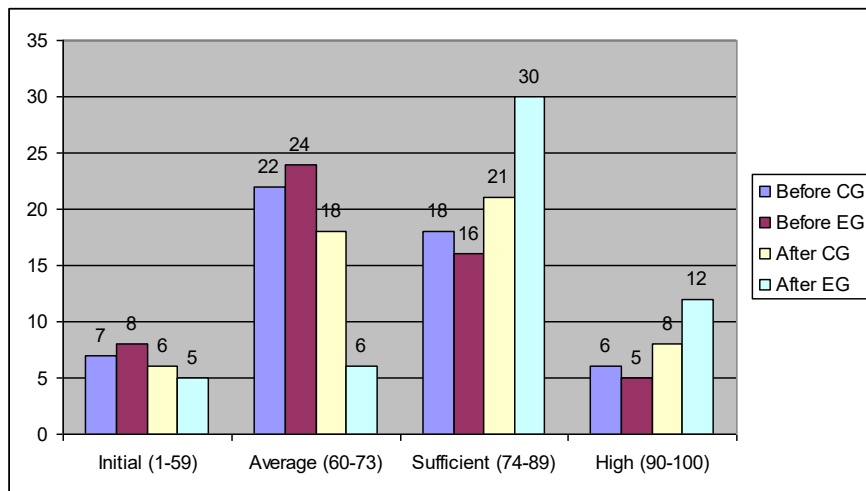


Fig. 12. Comparative distribution of students in CG and EG by the level of educational achievement at the beginning and end of the pedagogical experiment

As the statistics show the positive dynamics of a sufficient and high level of educational achievement in the experimental group, at the end of the pedagogical experiment, the Pearson χ^2 criterion was similarly applied. As a result, it was found that the sample had statistically significant differences at this stage, since $\chi^2_{\text{emp}} = 8,48$, $\chi^2_{\text{emp}} > \chi^2_{0,01}$.

This means that an experimental methodological training system for "Computer Networks" using MOOC is more pedagogically appropriate than the traditional one.

4 Conclusions

Finally, it should be emphasized that at the Zhytomyr Polytechnic State University Cisco Academy courses are introduced not only in the discipline of "Computer Networks", but also in the study of such disciplines as: "Fundamentals of Cyber Security", "Programming in Python", "C / C ++ programming" (within practice) and more.

In the future, it is planned to expand the network of Cisco Academy courses to schools, colleges, lyceums and other educational institutions of Ukraine.

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An Approach to ICT Professionals' Skills Assessment based on European e-Competence Framework

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Abstract. The main aim of this research is to increase project effectiveness in the ICT domain. In order to achieve this goal, it was decided to focus on a process of team formation, since a strong team is undoubtedly one of the most significant components of a successful project. To build a stronger and potentially more effective team from a wide range of candidates with different skills and knowledge, it is vital to determine the most eligible ones. Therefore, it is necessary to assess available candidates and to make this process effective, it has to be formalized and then optimized. To perform a fairly objective assessment of a candidate for a role in a project an approach using a comparator identification method is proposed to increase the effectiveness of the whole process. The European e-Competence Framework and ICT Professionals' Role Profiles documents are used to support this approach, and the appropriate software tool is designed to implement its main functionality.

Keywords: European e-Competence Framework, ICT Professionals' Role Profiles, Competence, Role Eligibility, Assessment, Software Tool.

1 Introduction: Problem Actuality and Research Goal

Information and Communication Technology (ICT) specialist's competence assessment is a process of determining whether this particular specialist is suitable for a role, for which an assessment is conducted. Role suitability is an ability to perform actions associated with this role in full and successfully [1, 2].

Such decision is based in our case on European e-Competence Framework (ECF) and ICT Professional Role Profiles (PRP) documents in order to formalize this process. ECF is a document that describes 40 competences for the ICT field. A competence is a demonstrated ability to apply knowledge and skills in order to reach observable results [3, 4]. PRP is a document that describes 30 typical roles performed by ICT specialists. A role is a set of responsibilities and actions performed by an individual within the project [5, 6]. Each competence can be presented on several levels (minimum 1,

maximum 5) and includes pieces of knowledge and skills needed for this competence [3, 4]. Each role, in turn, includes a set of competences (with minimum required levels) needed for this role [5, 6].

Comparator identification method is a special type of inverse identification. Input can be presented as a set of signals of any nature, output is 0 or 1. The idea is to determine whether input signals are in a particular relation, which is predetermined [7, 8].

As it is proposed in the integrated knowledge-based methodological framework for staff-training in IT-companies presented in [9, 10], it is critically important to elaborate an approach to an effective assessment of ICT professionals' skills.

The paper is organized as follows. Section 2 presents a short review of related work. It includes an overlook of several existing methods that can be applied to solve the problem, and a couple of software tools that use these methods. Section 3 provides a description of the proposed approach based on the comparator identification method with several detailed examples. Section 4 introduces an idea of what a software tool using proposed approach can seem like with its architecture design and user interface. Section 5 concludes the paper with a brief summary and an outlook on future work.

2 Related Work

2.1 Some Existing Methods in the Domain of ICT Professionals' Skills Assessment

Nowadays there are a couple of approaches that allow to determine one's ICT role suitability, but they are not agile and too subjective. That makes them ineligible for determination whether a specialist is suitable for a role or not in real projects. Consequently, the problem of role eligibility assessment is not formalized and does not have a specific solution, although several methods can be partially adapted for it.

Questionnaire method. Questionnaire method is an assessment method of a professional competence of a person in a chosen field based on self-rating [11]. Competence is assessed with competence index C , which is calculated by the formula:

$$C = \frac{C_o + C_a}{2} \cdot 100\%$$

C_o – Overall index, $C_o = 0.1 \cdot R$

R – Self-rating given on scale 1 to 10.

C_a – Aggregated index, calculated by a summarization of scores, obtained from a reference table on scale “Low”, “Medium”, “High”.

All importance indices ($k/S_{i,[low/medium/high]} - c_i$) for each knowledge and skill are predetermined. Knowledge/skill rating equals $\alpha * c_i$. Respondent chooses between options low/medium/high. After that, all ratings are summed and C_a is obtained [11, 12].

Simple equation method. The problem of the definition whether an employee matches an ICT Role can be solved by using a simple equation [13]. In this case, the equation can be presented:

$$R = \sum_{i=1}^n \left(\frac{L_i}{L_i^*} \cdot c_i \right) \cdot 100\%, \quad \sum_{i=1}^n c_i = 1$$

R – ICT Profile match degree presented as a percentage.

n – Number of Competences included in ICT Role description.

L_i – Level of respondents Competence.

L_i^* – Required level of Competence for ICT Role.

c_i – Competence importance index ($0 < c_i < 1$).

Respondents rate their competence level for each competence included in ICT Role description. Answers are then substituted into the equation [13, 14, 15].

Analytical model. There are plenty of methods regarding team formation automatization based on analytical models.

The idea to use analytical models to form project teams belongs to Zakarian and Kusiak. At first, their approach uses quality function deployment method to form project requirements. Then, a matrix of qualitative relations between requirements to the product and engineering skills is formed. Finally, team members are selected based on their skills with the help of analytical hierarchy process [16, 17].

Zakarian and Kusiak approach was then improved by Chen and Lin. They took into consideration not only engineering skills, but multi-functional knowledge, teamwork capability, and personal compatibility as well. The soft skills assessment relied on Myers-Briggs type indicator for personality profiling [18].

Another variation of analytical modelling usage was proposed by Fitzpatrick and Askin. Their model uses disjoint categories obtained by the division of labor pool. Their method focuses on emphasizes the interpersonal relationships by assuming that employees have the same level of skills. Heuristic method based on Kolbe measures is used for team formation, which provides good social construction [19].

Fuzzy logic. Fuzzy logic is a quite popular approach when it comes to team formation.

One of the approaches was proposed by Tseng and others. This approach uses grey decision theory for assigning specialists to specific roles in a project taking into account project requirements and their skills. Employees' skills are assessed in terms of fuzzy levels by others (usually department managers) [20].

Another approach, proposed by Karsak, uses linear programming for assigning specialists for specific roles in a project. Just like in a Tseng's approach, specialists' skills are presented by fuzzy numbers. Fuzzy values of skill requirements and importance degrees form a job specification and are used for preferential ordering [21].

Disadvantages of the methods. The methods described above have some serious disadvantages that significantly influence their effectiveness.

Questionnaire method is not adapted to ECF and its results do not map to the ECF competences levels, which makes it less attractive for wide usage. Moreover, this

method provides assessment only for competence levels and does not aggregate them into a role suitability level, which, in turn, makes it incomplete and usable only paired with another method that would calculate role suitability level based on competence levels.

Simple equation method does not consider specifics of each knowledge and skills competence pieces which significantly decreases its objectivity and makes its application in the real world questionable.

Methods based on analytical model are quite objective and accurate, but they tend to be very complex. Moreover, their adaptation to ECF and ICT PRP is either very difficult or even impossible which makes them inapplicable to our domain.

Methods based on fuzzy logic can be adapted to ECF and ICT PRP and provide result that is accurate enough. However, they are quite subjective since specialists' skills are assessed in fuzzy numbers by other people.

2.2 Available Tools for ICT- Competence Assessment Support

CEPIS e-Competence Benchmark. CEPIS has developed a free online tool for ICT professionals to assess their professional skills, based on European Competence Framework [14]. The tool allows respondents to check which of the ICT professional profiles matches them the best.

The assessment tool is presented by a questionnaire, where respondents select their own level of competence for each of them. Available level options are “None”, “Knowledge”, “Experience”, “Knowledge and Experience”. If the respondents select “Experience” or “Knowledge and Experience”, their choice corresponds to competence level (Dimension 3 of ECF).

The algorithm is based on a simple equation method. At first, Proficiency Index is computed for each of the 36 competences identified in the ECF, based on the respondent's answers. The index (expressed in percentage), represents the degree of proficiency for each competence with respect to the ECF. These scores are then compared with what is required for each of 23 ICT profiles. Finally, the result for each profile is given in a Proximity Index, expressed in percentage. This index indicates a role suitability degree [14].

EXIN e-Competence Assessment. EXIN has developed an online tool based on ECF and ICT Professional Profiles similar to CEPIS's [15]. It allows ICT professionals to find professional profiles, which match their skills best.

Respondents answer a questionnaire, where they select a competence level (Dimension 3 of ECF) and an extend level (“General”, “Partial” or “Superficial”) for each of 36 competences.

The algorithm is based on a simple equation method and consists of two main steps. At first, a level of competence proficiency (expressed in percentage) for each of 36 competences is computed by multiplying competence level by its extension level. Then, these scores are compared with what is required for each profile of 23 ICT profiles. A result is represented in Proximity Index, which indicates a role suitability degree [15].

2.3 The Proposed Method

After the described above analysis of significant disadvantages in existing methods, it becomes obvious that it is necessary to develop a new approach that would eliminate those serious flaws in order to provide an optimal solution for the problem. The approach should be based on a comparator identification method, which should significantly increase objectivity and allow deep connection to ECF and ICT PRP.

Comparator identification method is a method of indirect identification, which uses predicate logic for calculation. This method takes any types of data (signals) for input, but output is always binary (true/false or 0/1). Basically, this method allows to determine whether objects are in a particular relation or not [7, 8].

Method's feature of taking any data type for input allows full compatibility with ECF and ICT PRP, therefore, this method can be easily adapted to our domain. Binary output, in turn, allows to obtain a definite answer, which is in our case, "whether a specialist is eligible for a particular role in project or not?".

The following Table 1 gives the result of the methods comparison.

Table 1. Methods comparison

Method	Accuracy	Objectivity	ECF adaptation	Complexity	Completeness
Questionnaire	High	Medium	No	Medium	No
Simple equation	High	Low	Yes	Low	Yes
Analytical model	Medium	High	No	High	Yes
Fuzzy logic	Medium	Medium	Yes	Medium	Yes
Comparator identification	Medium	High	Yes	Medium	Yes

A comparator identification method provides a differentiated result in a binary form. Although it is not as accurate as in other methods, it meets the requirement of determination whether a specialist is suitable for a role in a project.

The main advantage of a proposed solution over other methods is high objectiveness and full compatibility with ECF and ICT PRP. High objectivity level is achieved by using predicate logic to strictly determine results for all possible cases. Flexibility of predicate logic, in turn, allows to fully adapt method to ECF and ICT PRP. All that makes the assessment process formalized and applicable in real projects.

3 Elaboration of the Proposed Approach

3.1 Assessment Methodology

Workflow description. An applicant for a role in a project is interviewed for knowledge and skills contained in the ECF competence description for each competence included in the Professional Role profile description. Based on the answers, a level for each competence and later – a role suitability degree – are determined using comparator identification method.

Algorithm. On the first step, respondent selects answers knows/doesn't know for each piece of knowledge and has/does not have for each skill (the fourth dimension) for each competence, needed for the role.

Then, the level of each competence is determined by the following predicate P_i :

$$P_i(x_1, \dots, x_n, y_1, \dots, y_m) = c_i, \quad i = \underline{1, k}$$

k – Number of competences needed for the role

x – Pieces of knowledge

y – Skills

c_i – Proficiency level of i^{th} competence

The predicate includes only levels, available for this particular competence. The predicate has the following internal structure, where $c_i = c_i^{L_{min}}$ or $c_i = c_i^{L_{max}}$:

$$\begin{aligned} c_i^{L_{min}} &= P_{L_{min}}(x_1, \dots, x_n, y_1, \dots, y_m) \\ &\dots \\ c_i^{L_{max}} &= P_{L_{max}}(x_1, \dots, x_n, y_1, \dots, y_m) \end{aligned}$$

L_{min} – Minimum possible proficiency level of competence

L_{max} – Maximum possible proficiency level of competence

The predicate is solved from bottom to top: if $P_{L_{max}} = 1$, then $c_i = L_{max}$, if $P_{L_{max}} = 0$, we go the predicate above and repeat algorithm until $P_{L_{min}}$ is reached. If $P_{L_{min}} = 0$, then the respondent does not have this particular competence.

Finally, after all competence levels are determined a role relevance degree is calculated by the following predicate:

$$P(c_1, \dots, c_k) = r$$

r – role fitness degree (1 or 0)

The result is obtained in the form suits ($r = 1$) or does not suit ($r = 0$).

3.2 Calculation of the Test - Examples

Example 1: Quality Assurance Manager. Let us suppose there are candidates for a vacant role of quality assurance manager in a new project, and they need testing in order to determine whether they suit this role (see Fig. 1).

Profile title	QUALITY ASSURANCE MANAGER ROLE (16)		
Summary statement	Ensures that processes and organisations implementing Information Systems comply to quality policies.		
Mission	Establishes and operates an ICT quality approach aligned with the organisation's culture. Commits the organisation to the achievement of quality goals and an encourages an environment of continuous improvement.		
Deliverables	Accountable	Responsible	Contributor
		<ul style="list-style-type: none"> Quality Performance Indicators ICT Quality Policy 	<ul style="list-style-type: none"> Quality Assurance Risk Management Policy
Main task/s	<ul style="list-style-type: none"> Establish and deploy the ICT quality policy Organise and provide quality training Provide ICT managers with quality performance indicators Perform quality audits Organise customer satisfaction surveys Assist project team members to build and perform project quality plans 		
e-Competences (from e-CF)	D.2. ICT Quality Strategy Development	Level 4	
	E.3. Risk Management	Level 3	
	E.5. Process Improvement	Level 4	
	E.6. ICT Quality Management	Level 4	
KPI area	Achievement of company quality goals		

Fig. 1. Quality Assurance Manager Role profile [5]

The role includes four competences. On the first step, our candidate will be tested to determine his proficiency levels for each competence. The determination of the competence level will be performed based on the answers in yes/no form for each piece of knowledge and each skill of the 4th dimension of the competence. The correctness of the results is supposed to be checked by company's technical specialists.

The first competence is D.2 - ICT Quality Strategy Development (see Fig. 2).

Dimension 1 e-Comp. area	D. ENABLE				
Dimension 2 e-Competence: Title + generic description	D.2. ICT Quality Strategy Development Defines, improves and refines a formal strategy to satisfy customer expectations and improve business performance (balance between cost and risks). Identifies critical processes influencing service delivery and product performance for definition in the ICT quality management system. Uses defined standards to formulate objectives for service management, product and process quality. Identifies ICT quality management accountability.				
Dimension 3 e-Competence proficiency levels e-1 to e-5, related to EQF levels 3 to 8	Level 1	Level 2	Level 3	Level 4	Level 5
	–	–	–	Exploits wide ranging specialist knowledge to leverage and authorise the application of external standards and best practices.	Provides strategic leadership to embed ICT quality (i.e. metrics and continuous improvement) into the culture of the organisation.
Dimension 4 Knowledge examples <i>Knows/aware of/ familiar with</i> Skills examples <i>is able to</i>	K1 the major information technology industry frameworks, e.g. COBIT, ITIL, CMMI, ISO – and their implications for corporate IS governance K2 the information strategy of the organisation K3 the different service models (SaaS, PaaS, IaaS) and operational translations (i.e. Cloud Computing)				
	S1 define an ICT quality policy to meet the organisation's standards of performance and customer satisfaction objectives S2 identify quality metrics to be used S3 apply relevant standards and best practices to maintain information quality				

Fig. 2. ICT Quality Strategy Development competence description [3]

The second competence is E.3 - Risk Management (see [3] p.44). The third competence is E.5 - Process Improvement (see [3] p.46). The fourth competence is E.6 - ICT Quality Management (see [3] p.47).

The following Table 2 presents answers for each competence.

Table 2. Questionnaire answers

	c^1	c^2	c^3	c^4
K1	x_1	-	-	+
K2	x_2	+	+	+
K3	x_3	-	-	-
K4	x_4			+
K5	x_5			+
K6	x_6			+
S1	y_1	+	+	+
S2	y_2	+	+	+
S3	y_3	+	+	+
S4	y_4		-	+
S5	y_5			+

The equation for determination of D.2 competence proficiency level is following:

$$\begin{cases} c^4 = x_2 y_3 (x_1 y_2 \vee x_1 x_3 \vee y_1 y_2) \\ c^5 = x_1 x_2 x_3 y_1 y_2 y_3 \end{cases}$$

The result for D.2 competence is: $P_1(\bar{x}_1, x_2, \bar{x}_3, y_1, y_2, y_3) = c^4$

The equation for determination of E.3 competence proficiency level is following:

$$\begin{cases} c^3 = x_2 y_1 y_2 \\ c^4 = x_1 x_2 y_1 y_2 (y_3 \vee y_4) \\ c^5 = x_1 x_2 x_3 y_1 y_2 y_3 y_4 \end{cases}$$

The result for E.3 competence is: $P_2(\bar{x}_1, x_2, \bar{x}_3, y_1, y_2, y_3, \bar{y}_4) = c^3$

The equation for determination of E.5 competence proficiency level is following:

$$\begin{cases} c^4 = x_1 x_2 x_6 y_2 y_3 \\ c^5 = x_1 x_2 x_3 x_6 y_1 y_2 y_3 (x_4 \vee x_5) \end{cases}$$

The result for E.5 competence is: $P_3(x_1, x_2, \bar{x}_3, x_4, x_5, x_6, y_1, y_2, y_3) = c^4$

The equation for determination of E.6 competence proficiency level is following:

$$\begin{cases} c^2 = x_2 y_2 y_5 \\ c^3 = x_1 x_2 y_2 y_5 (y_3 \vee y_4) \\ c^4 = x_1 x_2 y_2 y_3 y_4 (x_3 \vee y_1) \end{cases}$$

The result for E.6 competence is: $P_4(x_1, x_2, \bar{x}_3, y_1, y_2, y_3, y_4, y_5) = c^4$

After each competence level is calculated, it is possible to determine whether the candidate is eligible for the role. The following Table 3 presents the calculated competence levels.

Table 3. Levels of competences

D.2	c_1	c_1^4
E.3	c_2	c_2^3
E.5	c_3	c_3^4
E.6	c_4	c_4^3

The role suitability equation is given as:

$$r = c_2^3 c_4^4 (c_1^3 c_3^4 \vee c_1^4 c_3^3)$$

The final result equals: $P(c_1^4, c_2^3, c_3^4, c_4^4) = 1$ (The candidate fits the role).

Example 2: System Analyst Role. Let us suppose there is a candidate for a vacant role of system analyst in a new project, and this contender needs testing in order to determine whether he/she suits this role (see [5] p. 28).

The first competence is A.5 - Architecture Design (see [3] p.16). The second competence is B.5 - Documentation Production (see [3] p.24). The third competence is B.6 - System Engineering (see [3] p.25). And the last, fourth competence is E.5 - Process Improvement (see [3] p.47).

The following Table 4 presents answers for each competence.

Table 4. Questionnaire answers

	c^1	c^2	c^3	c^4
K1	x_1	+	+	+
K2	x_2	+	+	+
K3	x_3	-	+	+
K4	x_4	-	+	-
K5	x_5	-	-	-
K6	x_6		-	+
K7	x_7		-	
K8	x_8		-	
S1	y_1	-	+	+
S2	y_2	+	+	-
S3	y_3	-	+	-
S4	y_4	-	+	+
S5	y_5	+		-
S6	y_6			+
S7	y_7			-

The equation for determination of A.5 competence proficiency level is following:

$$\begin{cases} c^3 = x_1 x_2 y_2 y_5 \\ c^4 = x_1 x_2 x_3 x_4 y_2 y_5 (y_1 \vee y_4) \\ c^5 = x_1 x_2 x_3 x_4 x_5 y_2 y_3 y_5 (y_1 \vee y_4) \end{cases}$$

The result for A.5 competence is: $P_1(x_1, x_2, \bar{x}_3, \bar{x}_4, \bar{x}_5, y_1, \bar{y}_2, y_3, \bar{y}_4, y_5) = c^3$

The equation for determination of B.5 competence proficiency level is following:

$$\begin{cases} c^1 = x_1 x_3 y_1 \\ c^2 = x_1 x_3 x_4 y_1 y_4 (y_2 \vee y_4) \\ c^3 = x_1 x_2 x_3 x_4 y_1 y_2 y_3 y_4 \end{cases}$$

The result for B.5 competence is: $P_2(x_1, x_2, x_3, x_4, y_1, y_2, y_3, y_4) = c^3$

The equation for determination of B.6 competence proficiency level is following:

$$\begin{cases} c^3 = x_1 x_2 x_3 x_5 x_8 y_1 y_2 y_3 y_4 y_6 \\ c^4 = x_1 x_2 x_3 x_5 x_8 y_1 y_2 y_3 y_4 y_5 y_6 y_7 (x_4 \vee x_6 \vee x_7) \end{cases}$$

The result for B.6 is: $P_3(x_1, x_2, x_3, \bar{x}_4, \bar{x}_5, \bar{x}_6, \bar{x}_7, \bar{x}_8, y_1, \bar{y}_2, \bar{y}_3, y_4, \bar{y}_5, y_6, \bar{y}_7) = c^0$
(The contender does not have this competence).

The equation for determination of E.5 competence proficiency level is following:

$$\begin{cases} c^4 = x_1 x_2 x_6 y_2 y_3 \\ c^5 = x_1 x_2 x_3 x_6 y_1 y_2 y_3 (x_4 \vee x_5) \end{cases}$$

The result for E.5 competence is: $P_4(x_1, x_2, x_3, \bar{x}_4, \bar{x}_5, x_6, y_1, y_2, y_3) = c^3$

After each competence level is calculated, it is possible to determine whether the candidate is eligible for the role. The following Table 5 presents the calculated competences levels.

Table 5. Levels of competences

A.5	c_1	c_1^3
B.5	c_2	c_2^3
B.6	c_3	c_3^0
E.5	c_4	c_4^3

The role fitness equation is given as:

$$r = c_1^3 c_4^4 (c_1^3 c_3^4 \vee c_1^4 c_3^3)$$

The final result equals: $P(c_1^3, c_2^3, c_3^4, c_4^3) = 0$ (The contender does not fit the role).

4 Development of Software Tool for ICT- Professionals' Skills Assessment

4.1 Main Design Solutions

The software system is designed for ICT companies with a medium-to-large number of employees. Its mission is to automate the process of team formation, which should increase an overall project success.

The system should provide a functionality for project data management for company directors, team management for project managers and personal data management for all employees. Moreover, it should provide an opportunity for project managers to send employees project participation invitations and an opportunity for employees to apply for projects. Finally, one of the main of its features is an opportunity to test personnel for role eligibility to determine the best candidates and form an optimal team squad.

The defined functional requirements are shown on Fig. 3 in a form of a use case diagram.

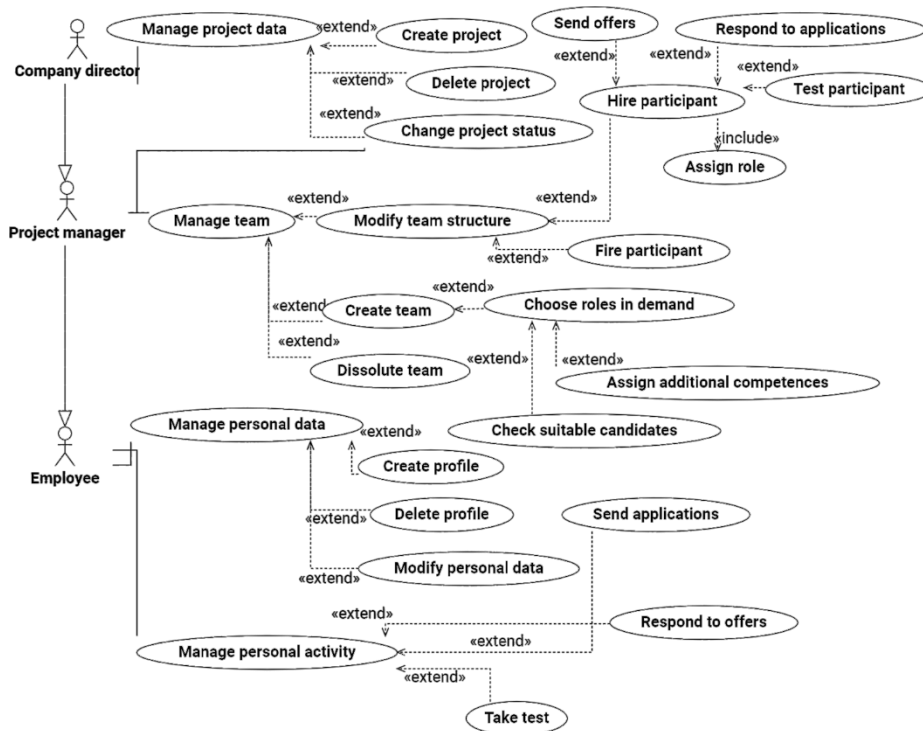


Fig. 3. Use case diagram for the functional requirements

Conceptual data model is given in the form of UML class diagram (see Fig. 4).

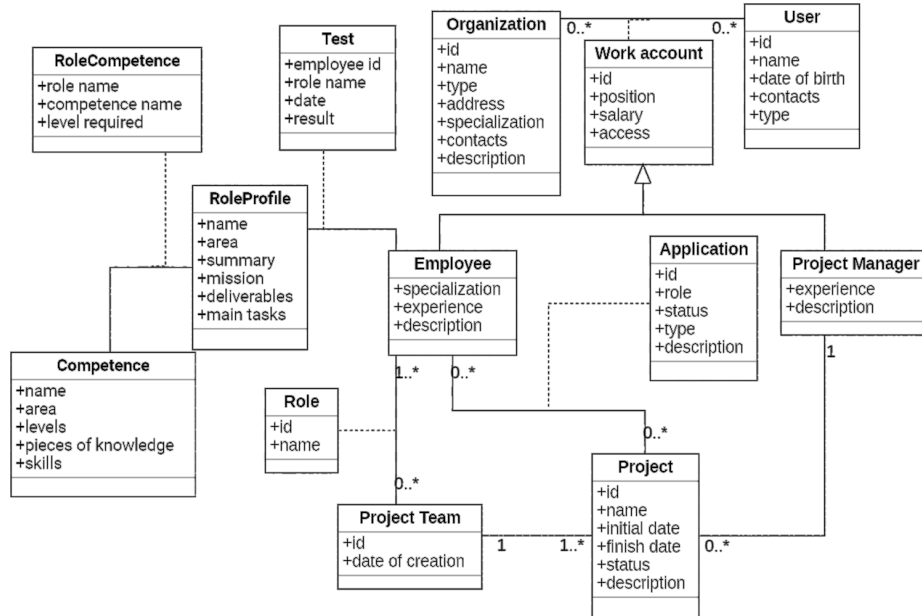


Fig. 4. Class diagram for the elaborated conceptual data model

“Competence” entity represents a competence from the ECF with all its attributes.

“RoleProfile” entity represents a role profile from the ICT PRP with all its attributes.

“RoleCompetence” entity represents a particular competence with its required level, included into a particular role.

These three entities are used to store ECF and ICT PRP documents in the database.

Database stores project managers (“Project Manager” entity) separately from all the other employees (“Employee”) because of their relation to projects (“Project” entity). Projects can have any amount of employees of any specializations (“specialization” field in “Employee” entity), but one and only one project manager.

“Project team” entity represents a group of employees that work on a particular project or several projects. All employees in a project team are assigned specific roles (“Role” entity), which they have in this particular project team.

“Test” entity represents a test taken by a particular employee for a particular role.

“Role” entity represents a role of a particular employee in a particular project team.

Several factors determine optimal architecture. The first factor is target platforms (mobile devices in our case). The second factor is database and server provider (Firebase by Google in our case). It was motivated by high accessibility and the fact that Firebase provides both server and database management system.

Considering these two factors, Rich Mobile Application architecture was chosen (see Fig. 5).

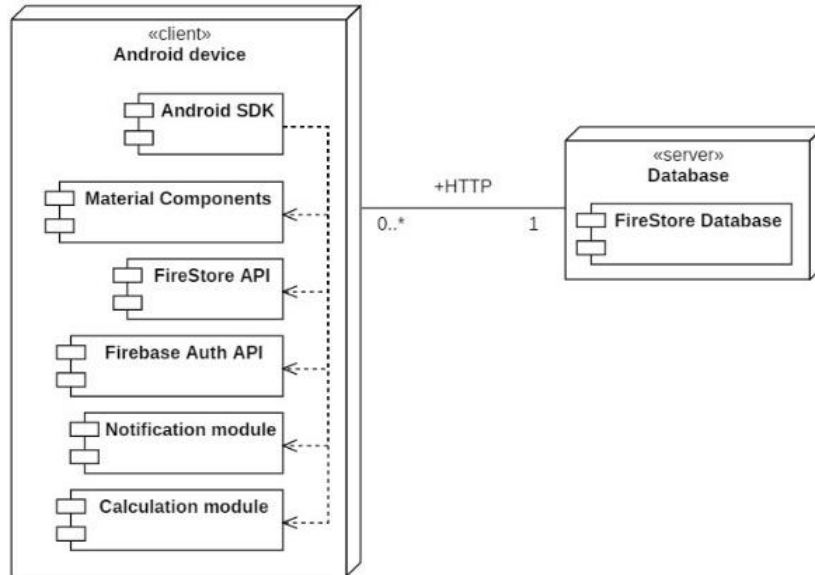


Fig. 5. Deployment diagram for the system architecture

On the basis of designed architecture and with regards to functional requirements, a software tool can be built. The prototype of such tool is shown in the next subsection.

4.2 Software Tool Prototyping

According to the functional requirements (see Fig. 3), the appropriate database model (Fig. 4) and the chosen architecture (see Fig. 5) as a prototype of a software tool was developed. Especially, on Fig. 6 and 7 the user's interface fragment is shown. Fig. 6 demonstrates options to analyze the project characteristics (Fig 6,A) and look through team's requirements (Fig 6,B). Fig. 7 demonstrates options to choose the appropriate workers from the list (Fig 7,A), and finally observe result of their skills testing with the ability to approve one of them for each project role (Fig. 7,B).

Fig. 6, 7 demonstrate the next case: There is a project (named "Example") for which a project team is needed. Currently, a team has a business analyst, a system architect, a tester and two developers approved. The next step is to approve an employee for a role of quality assurance manager. There are 3 candidates for this role with only two of them being suitable for it. A person responsible for a team squad formation chooses one of them and approves him/her for a role.

Usually, this process requires more people and time, as it is needed to form a pool of potential candidates, test every one of them, decide if they are eligible for the role, choose the best candidate and finally, inform everyone about the result. The suggested software tool automates this process so the choosing the best candidate is the only step that has to be performed manually.

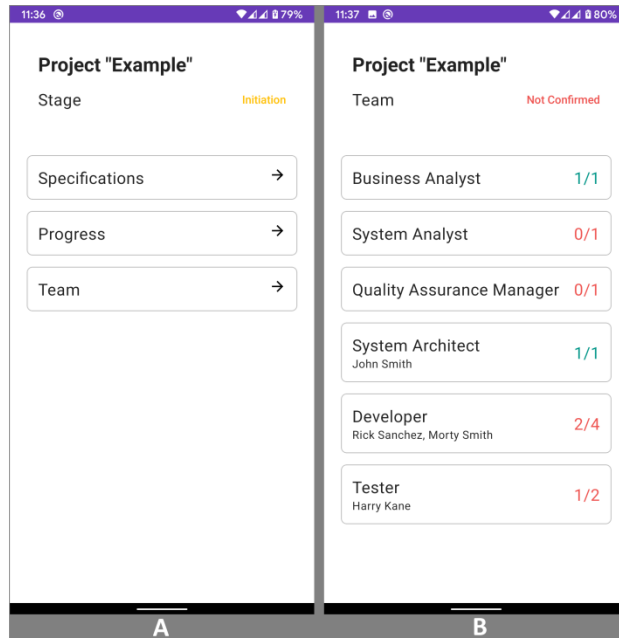


Fig. 6. Software tool prototype: candidate's data processing

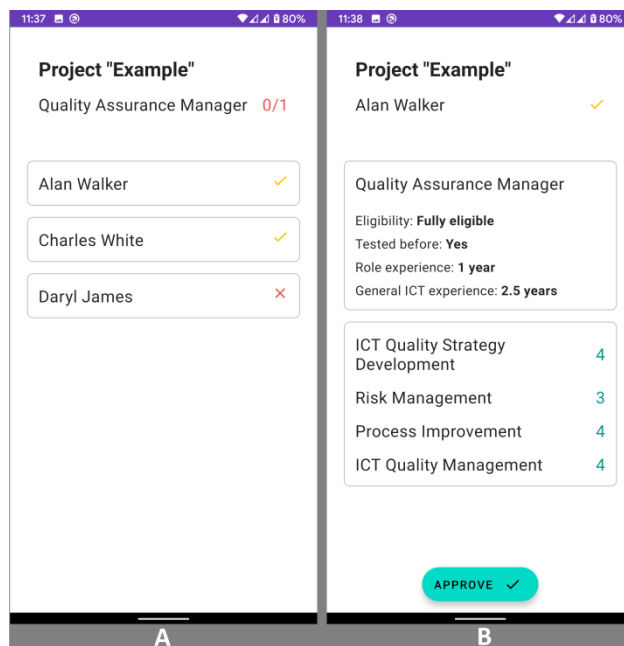


Fig. 7. Software tool prototype: final result for decision making

The experimental usage of the developed approach in the practice of candidates evaluating for an employment in the IT-company “Academy – Smart” LTD, Kharkiv [22] showed the processing time for appropriate data was reduced about 22%.

5 Conclusion and Future Work

This paper includes the overview of some existing methods, which can be used to perform an assessment of a specialist’s suitability for a particular role in ICT competences domain. Their weak points were determined and a new approach was proposed in order to eliminate them. Our approach is fully compatible with ECF and PRP documents and it is based on the comparator identification method that helps to increase the objectivity of the assessment result, because it calculates the quantitative parameters for this purpose. The experimental usage of this method has shown its feasibility in some real test – cases of IT-staff’s assessment.

Next steps to be done is a modification of our approach to increase its objectivity, in order to obtain more precise results that will help to make better decisions about potential team squad. In our future efforts, we also would like to elaborate a comprehensive methodology to test our approach not for selection of prospective candidates only, but with respect to a possible software product quality improvement in a target IT-company.

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Simulating Systems for Advanced Training and Professional Development of Energy Specialists in Power Sector

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Abstract. The crisis of the system of professional development and personnel training in the energy sector exists not only in Ukraine but also all over the world. The article describes the concept of development and functioning of the industry system of personnel training in the energy sector of Ukraine. The importance of using modern web-oriented technologies to improve the skills of operational and dispatching personnel in the energy sector of Ukraine is substantiated. The methods of distributed power system operating modes modelling are presented. Development and software tools for the construction of distributed simulating systems and particular features of cloud technologies application for the creation of a virtual training centers network in the energy sector, as well as the ways to automate the process of simulating scenarios development are described. The experience of introducing remote training courses for energy specialists and remote web-based training simulators based on a comprehensive model of the energy system of Ukraine is presented. An important practical aspect of the research is the application of software and data support for the development of personnel key competencies in the energy sector for rapid recognition of accidents and, if necessary, accident management. This will allow them to acquire knowledge and practical skills to solve the problems of analysis, modelling, forecasting, and monitoring data visualization of large power systems operating modes.

Keywords: simulating systems, simulators, professional development, operational and dispatching personnel, energy specialists, energy sector.

1 Introduction

In the developed Energy Strategy of Ukraine till 2035, one of the most important goals is integration into the EU energy space and strengthening of global ties [11]. The United Energy System (UES) of Ukraine integrates a large number of technological equipment distributed throughout the country intended for the generation, storage, transportation, distribution and use of energy. Highly qualified personnel must manage the operational management of power equipment. Insufficient staff qualification and lack of readiness to quickly eliminate emergency situations lead to major accidents and enormous material costs to restore energy supply [3].

It shall be noted that a considerable number of problems have accumulated in the Ukrainian energy sector now, and the main one is the lack of a single policy in the field of personnel education and training. The structure of the energy management system of Ukraine does not imply an organization, which could be responsible for the development of standard curricula and academic programmes for professional training of personnel, scientific and methodological and information support of the personnel training system, introduction of new technologies and best practices, achievements in science and technology. None of the organizations basically solves the tasks of providing the necessary level of qualification of the energy sector personnel, improving its efficiency and quality, quality control of general and special training of the personnel or testing personnel knowledge. At the same time, personnel development is one of the key tasks of the power industry leaders. The proper solution to this problem will increase productivity and ensure reliable, safe and accident-free equipment operation.

At present, the training and development of energy professionals are aimed at:

1. professional development for the formation of key competences in order to recognize the conditions of cyber threats, emergencies, and methods of their rapid elimination, which involves the application of theoretical and practical methods related to the processes of generation and distribution of energy, characterized by interdisciplinarity [5];
2. development of the ability to use information and communication technologies, introduce them to the latest developments, systems, software tools helping simulate and forecast the conditions of a complete power failure and develop the skills to use these tools in further professional activity;
3. training highly qualified and professional “industry elite” dispatchers capable of solving scientific problems and issues regarding the optimization of large power systems operating modes, as well as solving practical tasks of the digital transformation of the industry [4, 5].

The training and professional development system for energy industry personnel should be automated and remote to the extent possible, involving the use of training systems, cloud technologies and augmented reality [7, 8], to make it interesting and effective.

2 Literature Analysis and Problem Statement

Various causes of emergencies at energy objects are discussed scientists V. Artemchuk [20], B. Choi [10], K. Jeong [10], A. Iatsyshyn [20], V. Kovach [20], J. Moon [10], F. Paraschiv [27], O. Popov [20], M. Spada [27], et al. Design of mathematical and software tools for assessing the impact of fuel and energy enterprises on the economic component of the country and the environment [21, 22]; theoretical methods and practical tools for mathematical and computer simulation in the energy sector researchers I. Blinov [2, 14], O. Kyrylenko [14], A. Zaporozhets [33, 34], et al. The problems of creation and diagnostics of power equipment and simulating systems for the energy industry are described in [33, 34]. The problems of distance and blended learning of specialists in different fields have been the subject of study by scientists: V. Kukharenko [12], S. Lytvynova, [24, 28], S. Semerikov [17, 18], O. Spirin [28], T. Vakaliuk [16], et al. The features of power engineering and ecology specialists training and professional development in the field of energy and ecology have been investigated researchers E. Avetisyan [3], V. Gurieiev [3, 4, 5, 30], A. Iatsyshyn [13], V. Khoziyev [19], Y. Kutsan [13], V. Okhotin [19], V. Samoylov [26], O. Sanginova [3, 4, 5], et al. However, it is important to analyze and summarize the existing experience of using training systems to enhance the skills and training of energy professionals.

3 The Aim and Objectives of the Study

The purpose is to analyze and to summarize the experience of using simulating systems to improve the qualification and professional training of energy specialists, describe further directions of improving the system of professional development of personnel in the energy sector of Ukraine.

Tasks of the research:

1. To generalize the experience of applying simulating systems and substantiate the conceptual foundations of training and professional development system for specialists in the field of energy of Ukraine.
2. To identify the features of simulating systems development for energy.
3. To consider the principles of the development of objects and scenarios of simulating systems and identify the main directions of modernization of the system of training and professional development of specialists in the energy sector.

4 Research Results

4.1 Conceptual Foundations of Developing a Training and Professional Development System for Energy Sector Specialists in Ukraine

In the strategy of reforming the State Enterprise National Energy Company “Ukren-ergo” (SE NEC “Ukrenergo”) [29], professional staff development is one of the important elements of the strategy. It is planned to develop a corporate automated

knowledge and test database within the framework of the long-term personnel professional development system implementation. Its main reason is to develop training programs within the context of training centres, to implement game training and assessment methods during 2019-2020, and to refocus training on competency development and innovations, as well as practical improvement of technical skills by 2026.

It is important to plan state policy in the field of personnel training and professional development for a long period, to identify the sources of funding people responsible for providing all preparatory work, including the implementation coordination and monitoring.

The scientists of G.E. Pukhov Institute for Modelling in Energy Engineering of NAS of Ukraine, which have significant achievements in the energy sector, propose to develop a system of personnel professional development in the energy sector by integrating all educational institutions of the country carrying out energy research and providing energy-related education services into a new scientific and educational cluster in collaboration with other higher educational establishments and institutions [3].

The purpose of the proposed concept of the energy professionals training system is to organize a blended classroom and remote form of training and simulation applying information and communication technologies for the mandatory sustainable formation, verification, and control of key competences of the operational and dispatching staff of the energy sector of Ukraine. The competences to be mastered or developed by the personnel of the energy industry ensure the continuous reliable operation of the equipment and modes of operation of the UES and electric energy associations (EEA). They relate to the processes of dispatching control, organization of safe conditions of electrical equipment operation, recognition of accident causal factors and scenario analysis, formation and development of skills of quick emergencies elimination, techniques (rules) of regular and emergency switches at substations, in electric networks, etc. [3].

An analysis of the international experience of personnel training in the energy industry confirmed that the outlined competencies of staff can be formed solely with the help of full-featured simulators.

Currently, in Ukraine and in the EU, there are a large number of unresolved issues related to continuous education and professional development of UES and EEA personnel. Therefore, this problem requires further research and involvement of the world's best educational standards and learning technology.

In Ukraine, the issues of professional training of employees are regulated by the Laws and other guiding documents [6, 15], the obligations to maintain the proper level of staff competence are imposed on the management (employers' organization) of energy enterprises of all levels of the existing management hierarchy. However, practice shows that the capabilities of state-owned enterprise heads are now very limited by the amount of public funding. The existing system of professional development of energy personnel in Ukraine is based on the outdated intramural form of study as a part of compulsory training, once every three years 2-3 weeks long. In Ukraine, the most important component of operational and dispatching personnel development, which is a simulating system, is missing. This fact very much hinders the formation and development of the required staff qualification, for example, within the context of recognizing the conditions of occurrence and elimination of various accidents [3].

To date, the cost of business trips (travel, food and lodging) far exceeds the cost of training itself. These conditions of professional development make it difficult to form full-fledged homogeneous groups, adequate content of the educational and methodological base, and the use of effective methods of training and simulating system. There are also problems with the recruitment and training of instructional staff involved in professional development.

At present, an important trend for the social development of the world countries is the use of various information and communication technologies, in particular, virtual simulators in all fields of production activity, especially in the energy industry. In the energy sector of different countries European Network of Transmission System Operators for Electricity has created and successfully used a large number of electronic training systems and simulators. However, the major drawbacks of these systems are their narrow scope. Therefore, it is important to design and upgrade existing simulating systems, in particular, to develop their browser-based and mobile versions to use within the context of distance learning.

The implementation of the proposed Concept will be effective if we summarize the accumulated experience with the energy experience of the European Union countries and determine the membership of the main implementing organizations. The next step is to propose and agree with the SE NEC “Ukrenergo” a pilot project of an electronic simulating system by 2022, as well as to envisage the possibility of involving the European experts to the proposed concept of implementation.

4.2 Aspects of the Development of Simulating Systems for Energy Specialists Training

We agree with [25], that simulating systems for energy specialists training should be aimed at developing competencies and should be based on modern training technologies, including distance learning. An important component of the quality of staff training is the content of training programs, methodological support and a system of assessment of the quality of employee training.

The system of quality assessment of personnel training in the energy sector must necessarily include tools for measuring the level of knowledge, the ability to solve real, non-standard tasks, complicated by conflicting requirements, often in the context of incomplete or insufficient information, the ability of workers to synthesize and analyze situations arising in their professional activity.

In order to support high-level thinking and create the conditions for independent learning, simulating systems should provide staff with the ability to control employees' intrinsic motivation to learn, as well as the potential to create complex tasks that allow new information to be linked to the old one, find a place to personalize the experience, get acquainted with the experience of fellow professionals. Thus, these principles of organization of simulating systems training base guarantee personnel individual professional development, contribute to the acquisition of new knowledge and skills, affect the social improvement of staff, including the professional level and confidence in their knowledge [3].

Nowadays, blended and distance learning, which is a modern trend and has a significant impact on cost savings, should be used to enhance the skills of energy professionals. Blended learning combines classroom and e-learning technologies and is based on the application of information and communication technologies. The advantage of blended learning is that specialists can combine professional activities and learn at their own pace without wasting time.

An important element of distance learning is a distance-learning course. A distance-learning course should be designed to motivate students to work independently and actively interact with the system, to monitor the process and progress of learning. Therefore, the development of distance training courses for simulating systems applied by energy specialists requires high-quality teamwork of specialists - methodologists and experts in the energy sector - as well as the comprehensive application of didactic, technical and electronic training and control tools [19, 30].

The authors of this article and specialists from Scientific Production Enterprise LLC Infotech [9] have already developed a number of distance learning courses for distance learning and training of operational and dispatching staff in cooperation with the SE NEC "Ukrenergo", PJSC Kyivoblenergo and Center for the professional development of managers and specialists of the Ministry of Energy and Coal Mining of Igor Sikorsky Kyiv Polytechnic Institute: "Simulation System and Emergency Response Drill Using Full-Featured Web Mode Simulator", "Methods of On-line (Real-Time) Process Optimization of Operating Modes of the Unified Electric Power System of Ukraine", "Automated Preparation of Switch Cards at the Substations of the SE NEC "Ukrenergo", "Creating Emergency Response Drill Using HSC RS ++", "Designer-Editor of a Full-Featured Web Mode Simulator to Create Routine and Emergency Response Drill". These distance learning courses are designed to form and support operational and dispatching staff stable skills in eliminating accident initiation and progression at substations, as well as system and intersystem complete power failure in the power grids of the Ukrainian UES. Also, these distance learning courses have already been introduced into the educational process of educational institutions, which are subordinated to the SE NEC "Ukrenergo" and the advanced training centre of the Ministry of Energy and Coal Mining of Ukraine.

We believe that it is advisable to conduct a staff professional development process using blended and distance learning technologies in approved virtual research and training centers. Virtual training centers will upgrade the existing personnel training system in the energy sector, taking into account the new electricity market model [32], maximum possible staff qualification quality, and save human and financial resources.

4.3 Virtual Centers for Training, Assessment, and Simulation System for Energy Professionals

When developing a network of virtual research and training centers for training personnel in the energy sector, it is necessary to fully employ all elements of the existing infrastructure of the personnel training system: material, technical, educational and methodological bases and teaching staff integrating it into a single information environment. Creating a comprehensive environment will allow using all the experience

gained from the existing vocational simulating system in the energy sector and adapt the training programs to the needs of energy companies, the state and other stakeholders [3].

It is advisable to develop a network of virtual training centers in analogy with enterprise cloud computing. Virtualization is the main cloud computing technology and allows the creation of a single infrastructure of centers for personnel training, assessment and simulation system. Software tools developed to design, construct, and maintain a training facility of energy personnel simulating systems should support cloud architecture, virtualization, and blended and distance learning.

Nowadays, e-learning is widely used, therefore the software is being updated. There are several types of software products:

1. Copyright software. These are electronic textbooks, didactic materials, application software training packages and other elements of distance learning courses.

2. Content Management Systems. These include software products that support multiple users in a shared environment and are designed to create and modify digital content, such as text data, audio and video, program code, and more. The most well-known education-targeted content management systems with Ukrainian localization are Drupal and Joomla!

3. Learning Management Systems (LMS). LMS software is focused on learning activities management. The administration, documentation, tracking, and reporting functions are aimed at creating learning and development materials, and tasks such as providing training content to specific users at the right time, controlling the use of training resources, organizing interaction with the teacher, individual users and groups are automated. LMSs have the robust protection mechanisms required to deploy a distributed network of virtual training centers, can be synchronized with enterprise resource planning and personnel management systems. According to the research [1], the leaders are Blackboard, Canvas and Moodle software. Saba Software, SuccessFactors Learning, Voniz Inc., SumTotal Systems, Docent, WBT Systems, Click2Learn, and IBM are actively promoting their LMS products in the corporate market. Prometheus, Asnovator, Collaborator, and EDUGET worth mentioning among the products of the Ukrainian market.

4. Learning Content Management Systems (LCMS) are widely used in corporate computer networks. Unlike LMS, such systems focus on content management tasks, not the learning process, and are focused not on managers and students, but on content developers, methodological layout specialists, and project management executives. LCMS is based on the concept of presenting learning content as a collection of reusable learning objects with their target audience and specific context of use. Learning content management systems have only been actively implemented over the last few years, so the LSMS market is not mature enough, but the companies such as SAP (SAP Learning Solution), Oracle (iLearning and PeopleSoft Enterprise Learning Management) consider this type of e-learning not only as an infrastructure but also as part of the corporate IT infrastructure [3].

The LMS and LCMS systems discussed above have many things in common, as with the market expansion, LCMS developers are adding LMS-specific features and vice versa. LMS and LCMS have different goals: the main task of LMS is to automate the

administrative aspects of learning, and LCMS is focused on managing the content of learning objects. The common features are the following: both systems manage the content of the courses and track the learning outcomes, the built-in tools can manage and track the content to the level of the learning objects. At the same time, LMS can manage and track blended learning outcomes that combine E-content, classroom activities, virtual classroom meetings, and other resources.

Based on the analysis of the existing open-source LMS/LCMS systems, according to the software selection criteria, Moodle (Modular Object-Oriented Dynamic Learning Environment) was chosen as the instrumental simulating environment of the virtual training systems in energy sector [16]. The Moodle system is designed to create quality distance courses; it is used in 100 countries around the world by universities, schools, companies, and independent teachers. In terms of functionality, Moodle successfully competes with well-known commercial learning management systems, such as Canvas and Blackboard, at the same time it differs from as it is distributed in open source, which makes it possible to localize it considering the features of a particular educational project. Moodle integrates easily with other systems; in particular, it allows downloading packages such as SCORM, IMS or AICC as an archive and add them to the course. Additional packages extend Moodle capabilities: for example, an IMS package can be used to present multimedia content and animation.

A competency-based approach to training and professional development of personnel, implemented on the basis of virtual technologies, will allow the staff of not only the energy sector but also of other branches of the economy of the country to master the most important competencies and independent assessment of the level of professional training. Also, the problem of possible loss of experience, skills, and knowledge of retired staff will be solved through the remote involvement of retired senior specialists - to develop scenarios of emergency response drills and training exercises, participation in distance courses, expert discussion of predicted emergencies triggering events, their types, and elimination measures, etc. [3].

The development and implementation of distance learning courses are aimed not only at working energy professionals but also at undergraduate and graduate students, who will be provided with all facilities and opportunities of e-learning and training (based on common models of large UES and EEA and use of modern modeling tools).

4.4 Creation of Objects and Scenarios of Simulating Systems

A computer simulator for operational and dispatching personnel of the EEA and UES of Ukraine is a training tool that provides staff with the opportunity to adequately simulate the specified operating modes and operating conditions of equipment in the training process. It is vitally important for the formatting key competencies, in particular, recognition of conditions and causes of accidents, as well as the formation of stable skills for the rapid elimination of accidents [3].

In the published work [23], a computer training system is defined as a set of computer simulators modeling different functions of real equipment of EEA and UES with high accuracy in normal and emergency situations aimed at the personnel educational

process as a part of virtual research-educational centers (RECs). An important component of the computer training system is a simulation complex.

Currently, virtual technologies are not sufficiently involved in the development and use of mathematical, topological, information and computer models of simulating methods in distributed web-oriented environments [4, 5]. Such environments are often referred to as cloud computing, whose main purpose is to provide users with specific services [31]: OaaS, IaaS, PaaS, etc.

Developing full-featured mode simulators for energy professionals (see Fig.1), including management staff, is a complex scientific and technical task. The simulating system includes certain subsystems: management of distributed databases; modeling of operating modes of power systems; visualization of simulation results; human-machine interface and automated system for creating scenarios of regular and emergency simulation [3]. The latter subsystem should ensure the rapid creation of emergency response drills, using materials of investigation or anticipation of accidents. The list of such scenarios that will form the methodological basis of the training facility of the personnel simulating system.

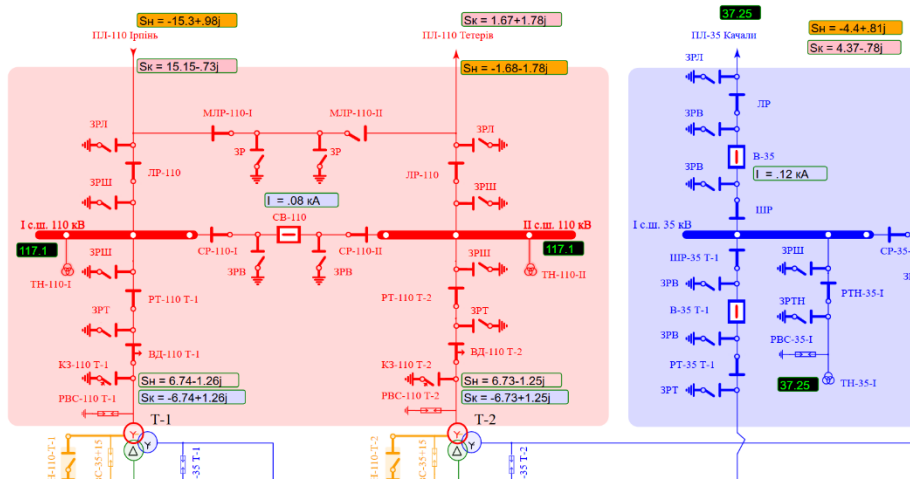


Fig. 1. An example of work full-featured mode simulators for energy professionals [9].

The published work [3] analyzes the existing approaches to the creation of training scenarios and the development of an automation system for the design of emergency response drills for remote web-oriented training simulators. The offered system of automation is intended for the organization of full training and methodological support of the personnel training process preparation both in the conditions of training centers and directly at workplaces. It is important to use a blended form of training around the clock for the operation and dispatching staff. The system of automated emergency response drills creation is realized taking into account features of the distributed environment of the power systems.

The main issue related to the simulating scenario design technology is the degree of completeness of the operational situations set that forms the basis of any personnel-training program. The experience of staff operational activity implies the importance of the instructor and training staff's personal experience when planning the training program. It is important to take an individual approach to staff training that allowing individually selecting content and planning a training program. The main difference between the proposed approach and the one described above is that the head of the simulation or training independently offers the conditions of the accident-triggering event. This allows focusing on the formation, control, and support of staff critical thinking skills and the ability to predict accident sequence. The generation of different possible or predicted options of situations greatly complements the algorithmic approach.

The publication [26] suggests a pedagogical scenario method of constructing simulation tasks based on the application of situational modeling methods. According to this method, the simulating complex and the object model - EEA and UES are used only at the development stage. The focus of the method is to create and use a model of personnel production activity according to job descriptions in the process of EEA and UES dispatch control. The scenario-simulating a pedagogical scenario method structure is formed as follows. After selecting the name, purpose, and task of the training task (TrT), a library of simulating procedures is created using the simulating complex (see Fig.2). The model of the operational and dispatching personnel activity is formed with the help of job descriptions, which regulate the required set of operations of dispatching control and are used as the object control model. It is advisable to use this method when designing the complex system and inter-system emergencies in terms of development and ways of elimination. Also when a possible alternative emergency development can lead to unexpected results in terms of the physical existence of the simulation modes.

The methods and algorithms of the formation of regression models of trunk electric grid (TEG) modes are developed, the ways of their use for the management problems solution within the process of carrying out the TrT of simulating systems (see Fig.3). This allows obtaining the results of simulation of different EEA and UES operational modes in the pace of time and with a comfortable reaction time required for the proper training. Comparative assessment of the first- and second-order regression models use for simulation of the modes allowed offering a convenient methodology for developing and organizing training systems and TrT models. This facilitates the work with the design and use features for the industry experts who have no programming skills. Switching programs can be written in the form of formal logical system for switching such as "run", "disable", "scan" and so on. This allows creating a task mini database to check the conditions of the performed or proposed operations in the form of a simple rule "if something happens or is completed, the result will be the following", which is then used to create emergency training scenarios and forms of routine switch cards [3].

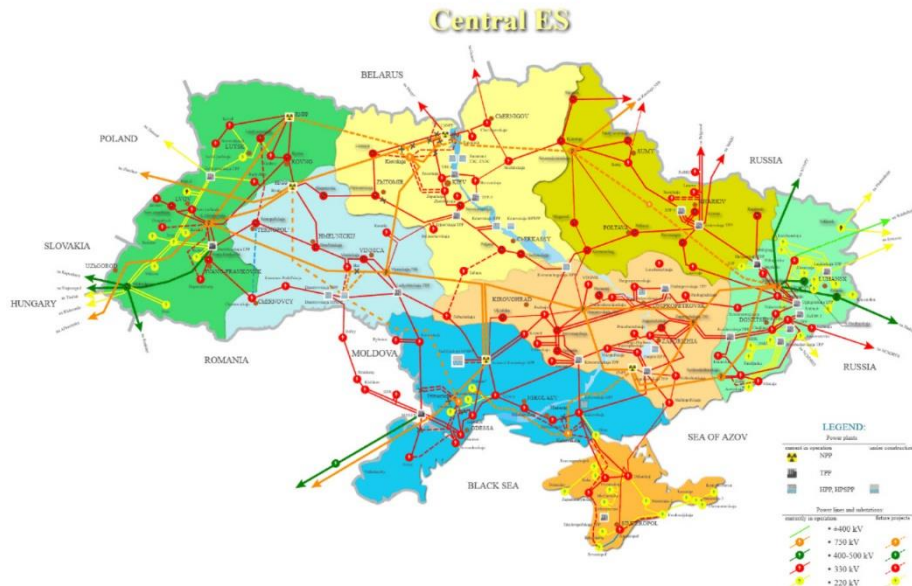


Fig. 2. Start page of full-scale simulator for operative staff.

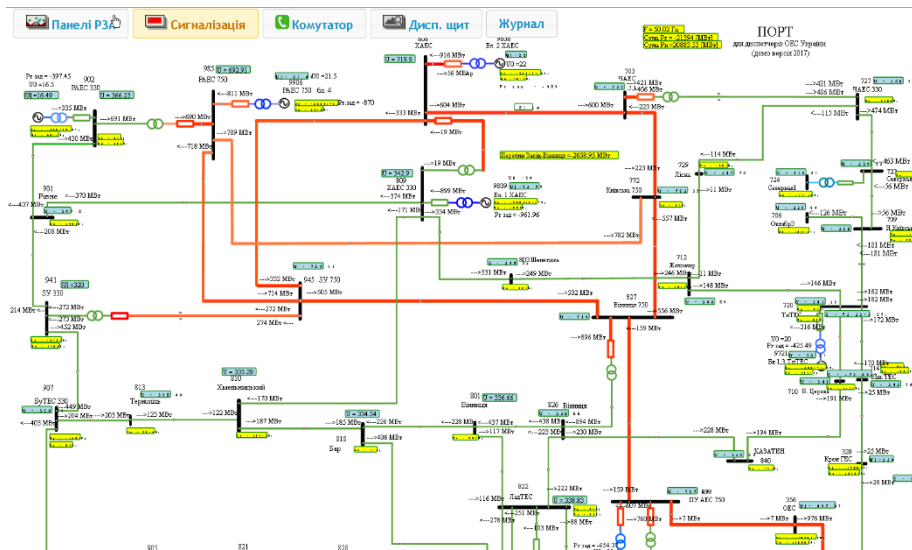


Fig. 3. An example of a large power systems scheme for constructing a TrT system.

The automation system of processes of design, editing, and creation of scenarios of regular and emergency training is developed for research and training virtual simulating centers. The proposed design system greatly speeds up the process of developing and

creating (editing) emergency training scenarios. The distributed simulating environment provides ample opportunities for effective use of the new modern electronic system of work with personnel and allows to move to the development of uniform standards of personnel training and simulating system for the energy sector of Ukraine. The combination of modern e-learning methods and tools of distributed virtual simulating environment allows creating a new quality of the system of professional development and training of specialists in the field of energy, including operational personnel of substations and power systems.

The significant contribution to solving the described tasks by G.E. Pukhov Institute for Modeling in Energy Engineering of the NAS of Ukraine, the Institute of Electrodynamics of the NAS of Ukraine, the Data Processing Centre of the Main Technical Directorate, as well as the higher education institutions, such as the National Technical University of Ukraine “Igor Sikorsky Kyiv Polytechnic Institute” shall be noted.

4.5 The Main Modernization Aspects of the Personnel Professional Development and Training System in the Energy Sector

We agree with the statement [3] that the current crisis in the system of personnel professional development and training in the energy sector exists not only in Ukraine but also in the whole world. The main unsolved challenges of the current system of professional development in the energy sector are:

- there are no national standards for the vocational-technical training of personnel in specific professions in the energy sector;
- the large number of the energy industry professions operating a variety of energy equipment and the lack of its unification significantly limits the development of a common approach (common professional development standards) to the creation of modern and effective simulating systems and training of energy industry personnel as a whole and requires considerable resources;
- practically all training and professional development programs applied in the respective industry-specific colleges are outdated and are usually focused on specific theoretical or practical issues, usually not relevant to the operation of EEA and UES equipment, and are based on electrotechnical principles and not on EEA and UES information models in general;
- there is no open general information and modeling environment for carrying out full-fledged studies, analysis and forecasting of normal and emergency modes of operation of UES and EEA, including all existing levels of the management hierarchy as a whole, in order to use the results of studies and calculations for simulating systems;
- full-featured mode simulators operating at the Ukrainian NPPs are the effective means of professional development and training. However, they are quite expensive and oriented, as a rule, to the simulation of specific NPP energy equipment, which complicates the transfer and application of the learned skills to eliminate accidents to other similar parts of large UES and EEA;
- there are no appropriate simulators as well as an educational and methodological framework for the operational and dispatching staff;

- the problem of losing the experience, skills, and knowledge of retiring staff. The solution to this problem is possible through the remote involvement of retired specialists with extensive experience in developing scenarios of emergency training and simulating exercises, expert discussion of predicted accidents triggering events;
- the lack of accessible open web-based resources for obtaining structured competency-based knowledge, including professional development and training of teachers and instructors, with mandatory control of their level of competence;
- there is no proper operational and long-term psychophysiological examination (diagnostics) of the personnel, testing, system of vocational and social rehabilitation;
- there are no scientifically sound criteria for determining the level of reliability by means of accessible verification (control) of key competences of the personnel, providing the basic technological processes of generation, distribution, and consumption of electric and thermal energy;
- there are no industry-specific standards of personnel professional development and training in the energy sector;
- there are no procedures and criteria for real-time proficiency testing of staff using a modern advanced training system and guaranteed by teachers' level of competence.

5 Conclusions

Today, the greatest challenge for the sustainable development of modern civilization is the reliable operation of power systems to generate and distribute energy to consumers of the right quality in the right volumes. In Ukraine, the main unresolved problems of the current system of professional development of operational and dispatching personnel in the electric power industry are: unregulated legislative support; outdated material and technical support; teaching and learning materials requiring updating and development; the greater part of the staff are close to retirement age or already retired, therefore, there is a need for young staff. The problems listed above cannot be effectively solved only through the creation of new educational institutions, the training of additional highly qualified teaching staff and the development of new training programs and training courses. Affordable and equal opportunities must be created for the continuous training of personnel of all energy enterprises in the industry. The solution to these problems is possible through the creation of a unified global corporate online network, combining educational institutions and virtual centers and training facilities as well as personnel professional development systems in a single unified structure with one main management and responsible authority. This could also be implemented as part of the development of an international virtual simulating center for innovative technologies and energy personnel training.

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The Use of ICT in the Flip Teaching of Future Mathematics Teachers

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Abstract. The article highlights possibilities of ICT in the implementation of the “flipped learning” technology in the professional training of future mathematics teachers. Flipped learning technology has been analyzed as a mixed learning model that has a different look at the organization of the educational process. The model of realization of “flipped learning” using ICT while studying the topic “Functions” in the course “Elementary mathematics” is developed. Given examples of the use of interactive learning technologies based on the use of modern information and communication technologies, including cloud and mobile. The lesson scheme of training on the technology “flipped learning” is described in detail using the system of Moodle, a shared virtual board, the use of QR codes during interactive technology “Bingo”. The peculiarities of using the Mentimeter online resource to conduct student surveys during reflection are disclosed. The results of student survey are analyzed and presented regarding the expediency of using this technology in future professional activity. It is established that the use of innovative teaching technologies in the process of professional training of future mathematics teachers contributes to the students’ awareness of the need to create and use of educational areas, which should become a powerful tool for students to develop critical thinking, self-disclosure of creative abilities, research skills, self-knowledge.

Keywords: ICT, cloud technologies, online resources, flipped learning, future math teachers, professional training.

1 Introduction

1.1 Formulation of the problem.

In modern conditions of reforming the system of national education, the problem of training a new generation by teachers capable of professional activities in the condi-

tions of transition of the world community to the information society becomes especially important.

As noted in the National Doctrine for Education Development in Ukraine in the 21st Century [17], one of the priority directions of educational development is the introduction of educational innovations and information technologies. In particular, the document emphasizes on ensuring the innovative nature of educational activities. Under these conditions, society expects a new teacher today (especially, a teacher of mathematics) who can only be trained in the innovative educational environment of pedagogical institutions of higher education. Only in the conditions of innovative environment it is possible to form a teacher who is a comprehensively developed, independent, self-sufficient personality, able to adapt quickly in the modern education system, to participate in its improvement, to be ready for the introduction of pedagogical innovations, namely a teacher-researcher, a teacher-innovator.

L. Vashchenko believes that the innovative environment of a particular educational institution should be filled with innovative content and forms of organization, provide conditions for the formation of new quality of professional scientific-pedagogical and management activities, thereby creating a powerful potential resource for development of professional activity [9, p. 39].

However, it is worth noting that at this stage a particular importance in the creation and efficient functioning of the innovative educational environment is the introduction of modern ICT in the educational process of higher educational institutions, thereby ensuring the gradual transition of the learning process to a new, quality level.

1.2 Analysis of recent research and publications.

The changes taking place in modern society and the reform of national education require the introduction of new educational technologies into the process of training future mathematics teachers. Among such technologies, the “flipped learning” technology, which is one of the key trends in the educational technologies of the present, is particularly widely used in the educational process.

“Flipped learning” is a model of the educational process in which the typical giving of lectures and the organization of tasks given for self-study swap places.

For the first time, the “flipped learning” technology in the educational process was used in the United States by chemistry teachers Aaron Samson and Jonathan Bergmann, who recorded videos of their lectures and offered them to students for homework.

“Flipped learning” technology is a modern trend in education that is of great interest to scientists. At the same time, it cannot be organized without the use of information and communication technologies.

The use of information and communication technologies in the educational process, in particular in the lessons of mathematics, was considered by such scientists as V. Bykov [8], M. Zhaldak [12, 13], K. Vlasenko [10], O. Spivakovskiy [18], N. Kushnir [18], S. Semerikov [6, 20], S. Shokaliuk [20], R. Ratushnyi [20], O. Markova [6], M. Popel [6].

The problem of introduction of the “flipped learning” technology into the learning process was considered by O. Danysko [11], O. Zymovets [14], V. Kukhareenko [15], N. Morze, L. Varchenko-Trotsenko [16], H. Tkachuk [19] etc. Among foreign scientists, the technology of “flipped learning” was studied by J. Bishop and M. Vergeler [2], J. Bergmann, A. Sams [1], M. Critz [3], C. Prober, C. Heath [7] and others.

V. Kukhareenko considers flipped learning as the organization of a course or a separate class, when “students study theoretical material remotely instead of traditional homework and then do practical work in the classroom” [15, p. 124].

O. Danysko [11] presented the models of traditional and flipped learning schematically (Fig. 1).

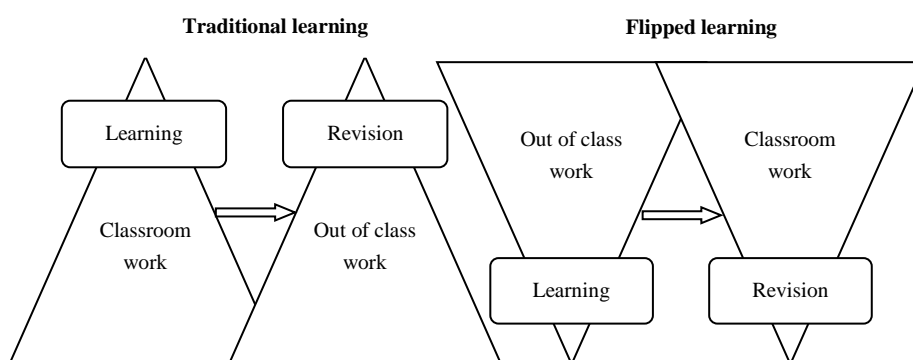


Fig. 1. Comparative models of traditional and flipped learning organization (by O. Danysko)

International organization “Flipped Learning Network” (FLN) interprets “Flipped Learning”; “Flip Teaching” as a pedagogical approach whereby the teaching process is shifted into an individual extracurricular space and the group space of the audience is transformed into a dynamic interactive educational environment for students mastering of educational material and its creative application [4].

“Flipped learning” as an educational technology must meet the following four characteristics [5]:

- Flexible Environment – allows you to use different modes of learning;
- Learning Culture – is student-centered;
- Intentional Content – aimed at supporting the conceptual understanding of the content of the educational course and its assimilation;
- Professional Educator – teacher professionalism is a key factor in ensuring the quality of the educational process.

2 Methods of the study

Methods used in the research process include: analysis of theoretical sources; analysis and generalization of domestic and foreign experience of the best pedagogical practices of using flipped learning in student preparation; monitoring the implementation of educational process and methods of activity of its participants; synthesis, gen-

eralization and conceptualization of development of main provisions of the study; development, substantiation and implementation of the model of “flipped learning” with the use of ICT during studying the topic “Functions”; student survey; analysis of the obtained data and descriptive statistics of the obtained results.

3 Results

One of the priority directions for modernizing the professional training of future mathematics teachers in pedagogical higher educational institutions is to combine traditional learning with the introduction of innovation, information and communication technologies. “Flipped learning” technology is a well-known combined learning model that allows you to take a different look at the organization of the educational process. The use of this technology involves the students’ preliminary self-study of the educational material presented in the form of a supporting compendium of the lecture or in the form of slides, video and audio materials. In the classroom, the teacher usually devotes time to explaining the difficult moments that most cause difficulties during the independent learning of the educational material, answers students’ questions about the topic of the class, organizes discussion of the studied material, etc.

The use of this technology in the professional training of future mathematics teachers contributes to students’ education of independence, responsibility, initiative, development of creativity, mobility, professional, communicative and digital competences.

Here is an example of the use of “flipped learning” technology in a practical class in elementary mathematics on the theme “Interesting world of functions around us”. The scheme of the class with all stages is presented in Fig. 2.

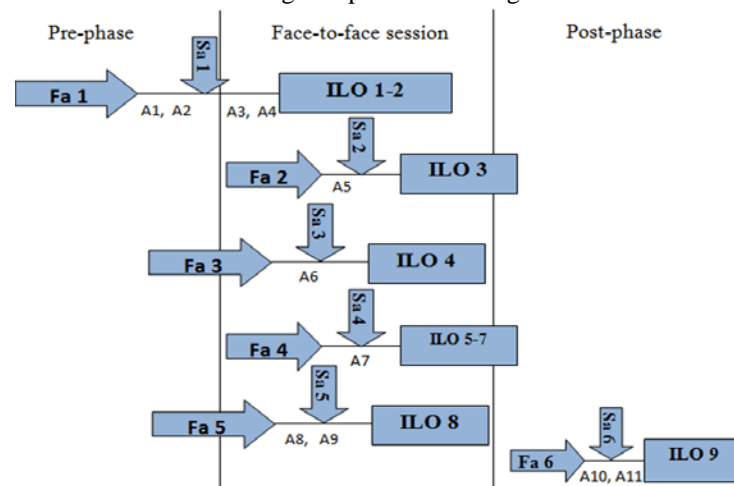


Fig. 2. The scheme of the class on technology “Flipped learning”
We describe the scheme where:

Formative Assessment (Fa) is an in-process evaluation that enables students to understand and track personal progress and plan for next steps with the help of a teacher. During the formative assessment, the teacher should constantly be close to the student and lead him / her to success, and at the Pre-phase and Post-phase stages this is possible due to information and communication technologies. The data that teachers receive during this assessment is used to adjust the learning and provide proper implementation of the tasks done by the students.

Summative Assessment (Sa) – final evaluation. This is the type of assessment that is used at the final stage of a certain period of study and its purpose is to assess the level of learning material. Using information and communication technologies, the teacher can conduct a final assessment not only during the lesson but also outside the classroom.

Pre-phase – work done before the class.

Face-to-face session – work with each other during the class.

Post-phase – work done after the class

ILO – intended learning outcomes.

ICT is often used on each stage of the lesson: it is a work in the MOODLE system and the use of a virtual board, and on-line survey, and the use of a SMART board for the presentation of student projects and watching videos, etc.

FA 1: Using the MOODLE system, students view materials (videos, photos, presentations, etc.), using forum, discuss, share experiences (ILO 1-2).

SA 1: The use of a shared virtual board, teacher assessment (frontal survey, express survey, online tests, etc.).

FA 2: working in groups (ILO 3)

SA 2: mutual student assessment

FA 3: development and presentation of student presentations (project) (ILO 4)

SA 3: student self-assessment, mutual student assessment, teacher assessment.

FA 4: individual and group performing tasks (ILO 5-7)

SA 4: teacher assessment

FA 5: watch video (ILO 8)

SA 5: general discussion, teacher assessment of responses

FA 6: implementation of individual homework and presentation of results to Moodle (ILO 9)

SA 6: general discussion on Moodle

FA 7: presentation of the finished project (ILO 10)

SA 7: mutual assessment and teacher assessment.

Pre-phace

ILO 1-2:

A1: students watching videos about types of functions and their properties;

A2: students discussing questions posted by the teacher on a forum on this topic

Face-to-face session

ILO 1-2:

A3: students' frontal survey of self-study material (3-5 minutes)

A4: liquidation of gaps (presentation of theoretical material) (7-10 minutes)

ILO 3:

A5: work in pairs to perform tasks on ready figures for definition (10-15 minutes):

- 1) the type of function;
- 2) types of performed elementary transformations of the function in a general form;
- 3) analytical record of the function presented in the figure;
- 4) properties of a given function.

ILO 4:

A6: Teaching division of students into groups to explore the use of functions and their graphs in the environment (mini-project “The World of Functions Around Us”) (10-15 minutes):

- 1) medicine;
- 2) architecture;
- 3) nature;
- 4) science.

ILO 5-7:

A7: individual and group performing tasks (10-15 minutes):

- 1) graphing the function set analytically in the standard form
- 2) the simplest transformation of graphs of elementary functions
- 3) determining the type of function according to a given graph

ILO 8:

A8: students watch a teacher-prepared video showing some examples of function graphs in the environment (2-3 minutes)

A9: presentation of the mini-project results “The World of Functions Around Us” (13-17 minutes)

Post-phase:

ILO 9:

A10: develop a fragment of the lesson in learning types of functions with the obligatory inclusion of material from a mini project:

- 1) 7th grade
- 2) 8th grade
- 3) 9th grade

A11: posting developed fragments of classes on Moodle for general discussion

According to Bloom’s taxonomy, the result of the training was to obtain the following expected learning outcomes (ILO), which are shown in table 1:

Table 1.Expected learning outcomes on topic “An interesting world of functions around us” using “flipped learning” technology

Levels	Expected learning outcomes
Knowledge:	ILO 1: content of the concept “function”, “graph of function”
	ILO 2: types of elementary functions
Understanding:	ILO 3: properties of elementary functions
	ILO 4: practical use of functions in everyday life
Application:	ILO 5: perform graphs of elementary functions
	ILO 6: make elementary transformations of function graphs
	ILO 7: define the general kind of function by graph
Analysis	ILO 8: graphs of functions in the environment (nature, science, architecture, medicine, etc.)

Synthesis:	ILO 9: combine and adapt the acquired knowledge and skills in future professional activity
Evaluation:	ILO 10: the quality of the educational project (in the process of independent search)

An example of a developed Moodle lesson is shown in Figure 3.

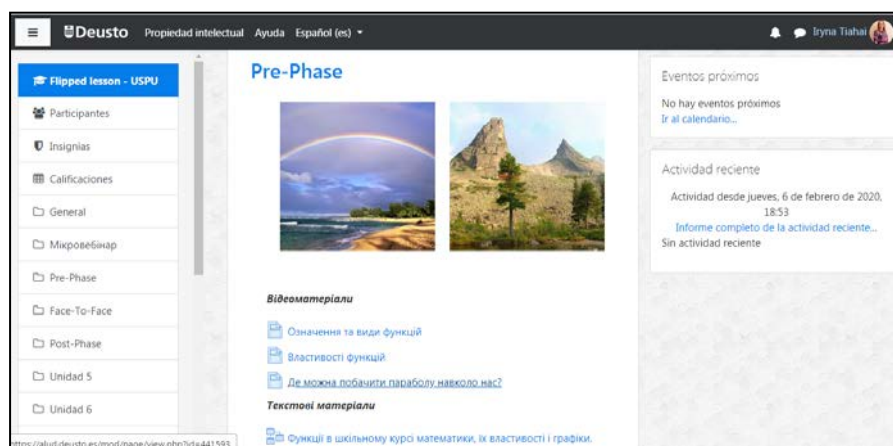


Fig. 3. Developed lesson using the “Flipped learning” technology in Moodle

This form of work in higher education will promote the formation of general and professional competences in students. In addition, to teach future math teachers the use of innovative technologies, we use “Bingo” technology in the frontal survey. This is a fun game that will help to activate students’ mental activity, set them up for active learning. We offer students a QR code that gives them the task of collecting a puzzle or finding matches, etc. Whoever does the task first says Bingo! and becomes a winner in this game. An example of the use of such a task in training elementary mathematics on the topic “An interesting world of functions around us” is shown in Figure 4.

After watching a video clip prepared by the teacher, which provides some examples of graphs of the function in the environment, we suggest students to watch a small video clip of a physical activity break. Such a video (Fig. 5) will be useful for future teachers when learning this topic at school.

The final stage of this class is the reflection. Various online resources were explored to interact with the audience. There are a lot of such cloud resources. To select such a resource, the following three criteria were used: intuitive interface (no need to read the instructions), lack of registration for students (for the content creator it is necessary), multifunctionality (the resource can be used in any part of the lesson performing different tasks). One of these online resources is Mentimeter.

Mentimeter is an online resource for creating presentations, surveys, real-time surveys, allowing you to get instant feedback from the audience.

So, at the end of the lesson, we offer students to answer the following questions:

1. Did you enjoy working with “Flipped learning” technology? (Options: Yes; it was good; not good; no).

2. Will you use today’s online services in your future professional activities? (Options: Yes; rather yes; sometimes; I don’t know; no).

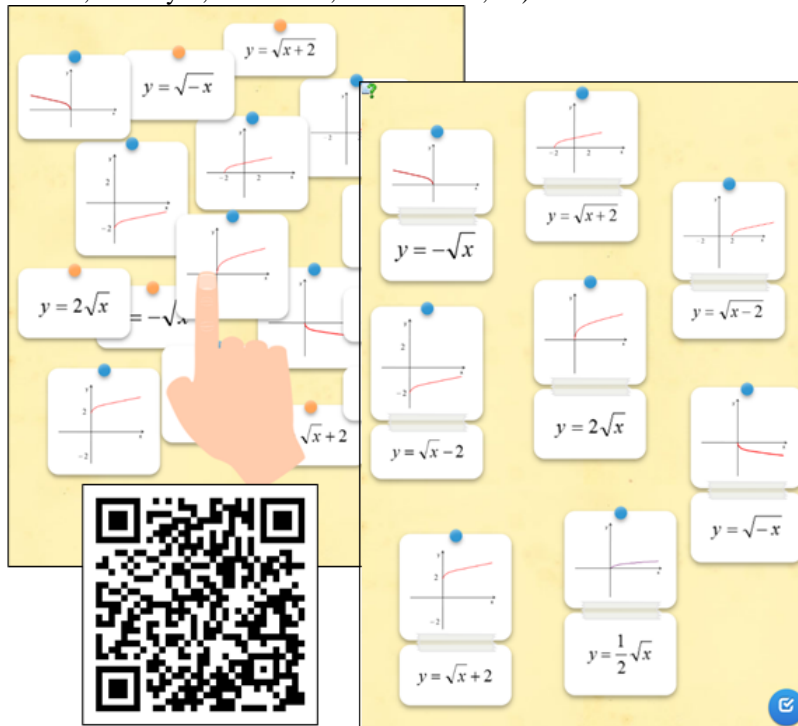


Fig. 4 Using QR Codes during interactive “Bingo” technology

To conduct an audience survey, you need:

- Teacher with PC with the image broadcast on the screen;
- Students with smartphones or tablets with Internet access.

The teacher runs the survey from the PC in the classroom. The screen shows the address and code of the survey for students. Students, using smartphones or tablets, go to www.govote.at, enter the survey code and answer the questions. The survey results are displayed instantly.

It is possible to conduct surveys both in synchronous mode (in the audience, “here and now”), and in asynchronous mode – at any time within the specified interval of the survey.

Anonymous voting can be effectively used as a formative assessment tool when it is necessary to determine the overall level of understanding the topic by students. It has several advantages, such as:

- anonymity allows the respondent to avoid stereotypical thinking and express his or her own opinion;

- lack of criticism or negative evaluation by others makes it easy for respondents to express themselves;
- the results will be more accurate, if there's no pressure on the part of others;
- anonymity allows to avoid negative dominative opinion of one or more voting participants.

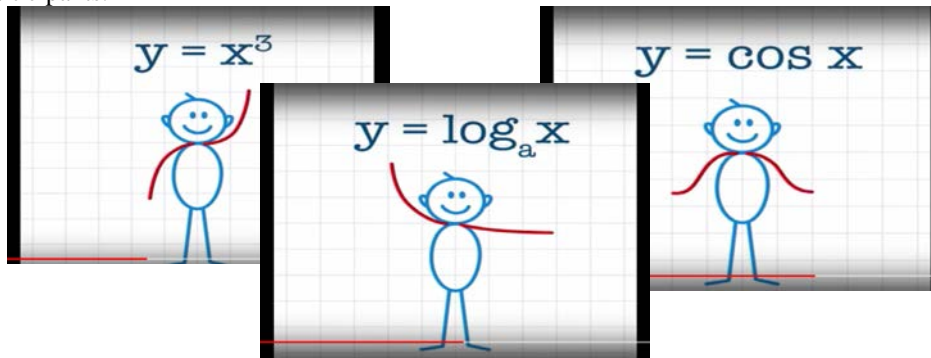


Fig. 5 Video clip-physical activity break

27 students from the Faculty of Physics, Mathematics and Informatics of the Pavlo Tychyna Uman State Pedagogical University participated in the survey. The results of the survey are presented in Figures 6 and 7.

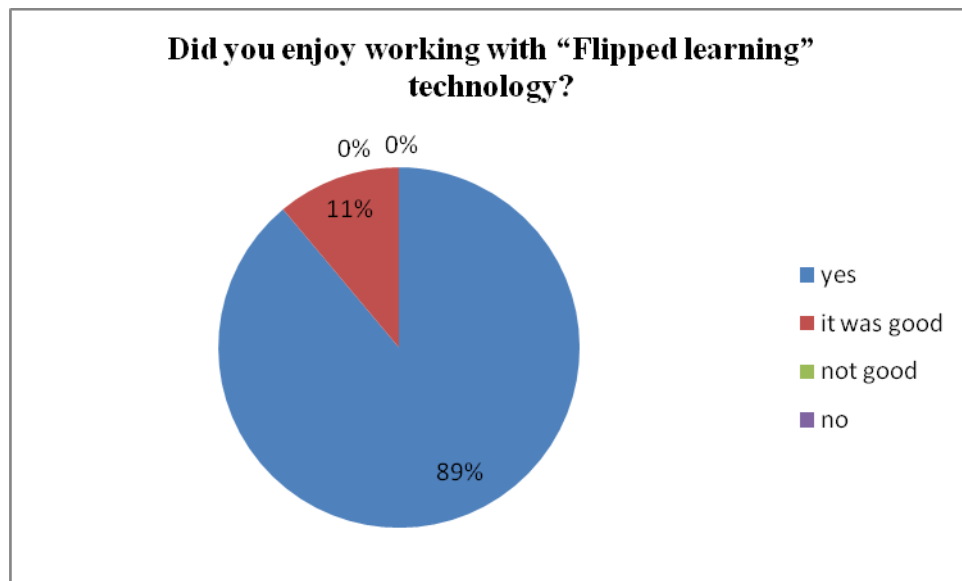


Fig. 6. Student survey results

The interaction of participants of the educational process in an interactive form should be applied at the classes as often as possible, so that future teachers can successfully and skillfully implement them into their professional activities, thus turning learning into a game and engaging students in mathematics, because in such mathematics classes it will be not only be cognitively but also fun and not boring.

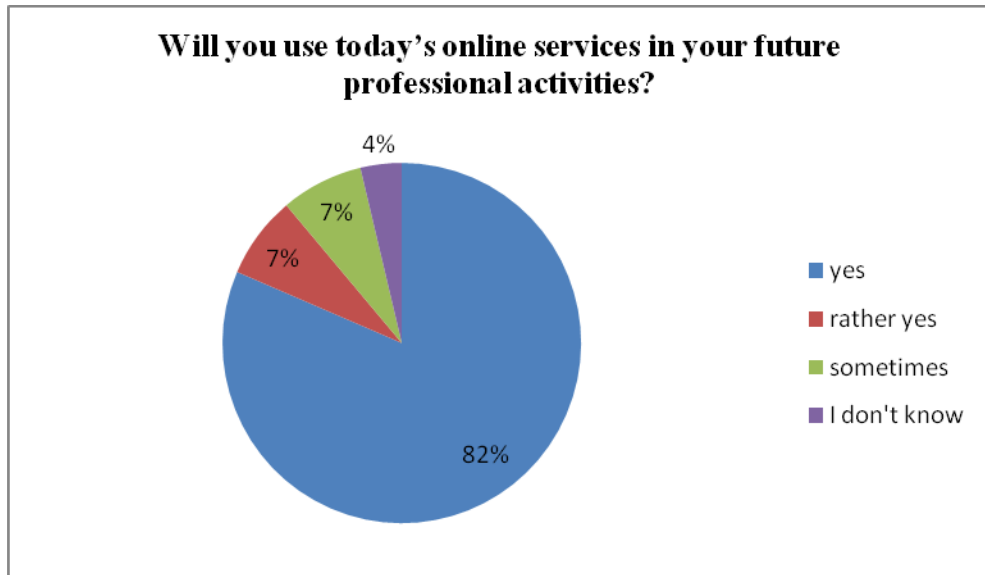


Fig. 7. Student survey results

4 Conclusions

So, one of the important tasks facing the modern teacher of mathematics is to modernize the learning process by providing it with a creative and active character in order to shape students' life competencies. Practical methodological skills of future mathematics teachers should become a tool for building effective pedagogical interaction in the process of teaching mathematics to students. The use of innovative teaching technologies in the process of methodological training of future mathematics teachers promotes students' awareness of the need to create and use of educational spaces, which should become a powerful tool for students to develop critical thinking, self-disclosure of creative abilities, research skills, self-knowledge.

An effective form of organization of the educational process which provides student mastery of pedagogical innovations based on information technology and modern means of communication is flipped learning. This technology creates the conditions under which future teachers of mathematics take responsibility for the process and outcome of personal learning and learn to carry out future professional activities in the context of globalization and informatization of society.

Further research should be directed to the use of the proposed technologies in teaching students of professional disciplines.

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Electronic Textbooks for Ukrainian Education: Statistics, Models of Development, Quality Problems

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ABSTRACT. The article provides the result of scientific research on developing electronic textbooks (e-textbooks) for Ukrainian schoolchildren. The aim of this empirical research was to compare e-textbooks development in 2018 and 2019, found out the major players in the Ukrainian e-textbook market for general secondary education institutions, the level of e-textbooks' provision in primary, middle and high schools, subjects that are most popular among Ukrainian e-textbooks publishers.

It was found out that the number of e-textbooks publishers has grown from 5 in 2018 to 9 in 2019, the largest number of e-textbooks for schoolchildren were developed for the 1st grade students (19 e-textbooks), the least number for the 11th grade students (2 e-textbooks). It was developed the most e-textbooks in the subjects "I explore the world" and "Mathematics" for the 1st grade (7 and 5 respectively).

The study identified and described two e-textbooks development models of Ukrainian publishers (outsourcing and standalone) and the platforms they used. An outsourcing model was used by 6 publishers, a standalone one used by 2 ones; 19 e-textbooks were produced using the first model; 27 e-textbooks were developed using the last one. Two of the publishers developed e-textbooks using both models. The most popular platforms for e-textbooks developing were the platform of the Multimedia Publishing House Rozumnyky (14 e-textbooks) and the mozaBook Editor program of the Hungarian company Mozaik Education (15 e-textbooks).

It was outlined some quality problems of developed e-textbooks and suggested the directions for further improvement of e-textbooks.

Keywords: electronic textbook, models of electronic textbooks, quality of electronic textbooks, requirement for electronic textbooks.

1 Introduction

The transition of Ukraine to the digital stage of development has led to the need to reform the educational sector, including the use of modern technologies for teaching. Nowadays, teachers are increasingly using electronic educational resources (EERs) in lessons to increase students' interest in learning, to optimize their learning time, to build an individual educational path, to explain or consolidate new learning material, or to test the generation that is born in the digital era with more efficient way.

The formation of the modern information and educational environment of an educational institution enables learning anywhere, anytime, stimulates the cognitive activity of students, automates the process of control over their educational achievements, promotes individualization of the learning process, etc. Essential components of such an environment are the EERs, including one of their varieties, namely an electronic textbook (e-textbook).

The definition of an e-textbook, the understanding of its role in educational process experienced significant changes over the last decade. While an e-textbook considered an electronic copy of a paper textbook ten years ago, now the electronic copy of a textbook (pdf version) and an e-textbook are clearly distinguished in Ukraine. There is an opinion that e-textbooks can only supplement print publications, but the Ministry of Education and Science of Ukraine plans to switch completely to electronic textbooks in schools over time.

The updating on the material and technical base of schools, the modernization of forms, methods and teaching aids, the development of a legal framework for the introduction of latest technologies in educational process are taking place in Ukraine nowadays. At the state level, some important documents have been adopted such as the Regulations on EERs, Distance Learning Regulations, Digital Economy and Society Concept for 2018-2020, Regulations on an e-textbook.

For the first time at the state level in Ukraine, the concept "electronic textbook" was introduced in the Regulations on electronic educational resources in 2012. Now this concept is also duplicated in the Law of Ukraine "On Education" and the Regulations on an e-textbook. All these documents state that "the electronic textbook (manual) is an electronic educational publication with a systematic presentation of educational material that is relevant to the educational program, contains digital objects of various formats and provides interactive interaction" [1, p. 4]. In our study, we understood the "e-textbook" exactly as it is defined at the state level.

Many scientists studied the implementation of e-textbooks in the system of Ukrainian vocational and higher education. The development of e-textbooks for vocational education institutions was studied by A. Guraluk, O. Didenko, H. Yelnikova, V. Lozovetska, P. Luzan, V. Shvets, V. Yurzhenko, L. Gumenna, A. Zueva, V. Lokshin, M. Rostocka, I. Shupik, who published "Guidelines for the development of an electronic textbook for vocational schools" in 2014 [2]. The technology of creating an interactive EER in the format of an e-book (notebook) to accompany a laboratory workshop on physics was explored by the authors who noted that it "combines interactive elements, visualization of processes, calculations, reporting, feedback with a teacher, and has a web page format suitable for viewing on different computers, using different browsers, with the possibility of uploading it to the Internet" [3, p. 265–266].

E-textbooks for general secondary education are less studied than other types of EERs. Ukrainian scholars mainly studied the EERs for schoolchildren (papers of V. Bykov, S. Lytvynova, O. Melnyk [4], et al). There are only few papers that are devoted to modern Ukrainian e-textbooks for schools. The articles of A. Antokhova [5], L. Iliichuk [6], S. Lytvynova [7], V. Kosyk, O. Melnyk [8], I. Vorotnykova [9], M. Zhenchenko [10] are worth mentioning here.

A. Antokhova [5] offered a comparative characteristic by different criteria (design, operating system, access conditions, types of tasks, etc.) of two e-textbooks for the 1st grade, namely “Art”, developed by the Multimedia Publishing House Rozumnyky and “I explore the world”, developed on the platform mozaWeb. L. Iliychuk [6] described the number of interactive tasks, interactive games, audio, video material in four e-textbooks for the 1st grade, namely “Art” and three e-textbooks from the integrated course “I explore the world” by different authors. S. Lytvynova [7] described and justified the use of Smart Kids technology and e-textbooks in elementary school educational process. She also analyzed the results of a survey of elementary school teachers conducted in 2018 regarding their attitude to the new type of textbooks. M. Zhenchenko [10] analyzed the editorial and publishing specifics of the e-textbooks for the 1st grade students developed in 2018.

The analysis of the scientific sources has shown that there is insufficient research on the development of Ukrainian e-textbooks for schoolchildren. This may be because the development of e-textbooks for Ukrainian schoolchildren is a new phenomenon and the active process of developing such e-textbooks in Ukraine began only two years ago. The impetus for this was the approval of the Regulations on an e-textbook in 2018 and the request of the state for their development in 2018 and 2019. The latter motivated publishers to develop 46 e-textbooks over the last two years. They have become the focus of our study. It was carried out within the framework of the research work “Development of information educational environment of a modern educational institution of Ukraine” (state registration number 0117U006234).

The study focuses on the analysis of e-textbooks for general secondary education institutions created in 2018 and 2019 by national developers at the request of the state over the last two years and submitted to the committees of the Scientific and Methodological Council of the Ministry of Education and Science of Ukraine.

The objective of this paper is to analyze the e-textbooks for Ukrainian schools developed by the Ukrainian publishing houses for:

- identifying major players in the Ukrainian e-textbook market for general secondary education institutions;
- study of e-textbooks’ provision for primary, middle and high schools;
- determination and description of e-textbooks’ development models used by the Ukrainian publishers;
- identification of the directions for further improvement of e-textbooks following the requirements of the international standard DSTU ISO/IEC TR 18120:2018. Information technology — Learning, education, and training — Requirements for e-textbooks in education (ISO/IEC TR 18120:2016, IDT) [11] that has been adopted in Ukraine recently.

All these steps will be able to improve the e-textbooks’ quality, which will affect the effectiveness of digital education in Ukraine.

2 Research methodology

The study of electronic textbooks for Ukrainian schools was realized in several stages. At the first stage of the study, a bibliographic method was used to identify and systematize scientific sources, regulatory documents on the problems of e-textbooks' creation. The second stage involved the collection of empirical data on e-textbooks developed by Ukrainian publishers in 2018–2019. The third stage was dedicated to the processing data using methods of analysis, synthesis, summarizing and others.

The main sources of empirical data were e-textbooks developed by Ukrainian publishers in 2018–2019, presented on the website of the Institute for Educational Content Modernization. The number of e-textbooks developed during 2018–2019 is taken from the minutes of the meetings of the Commission on Informatization of Educational Institutions, prepared by the staff of the Digital Education and ICT Department of the Institute of Educational Content Modernization. The information on which e-textbooks have been evaluated and recommended for use in the educational process is obtained from the website of the Institute of Educational Content Modernization (the order of the Ministry of Education and Science of Ukraine № 1338 of 24.10.2019). Some informal interviews were conducted with publishers of e-textbooks and developers of platforms for e-textbooks in order to identify the specifics of e-textbooks development.

The collected empirical data were summarized and systematized using common scientific methods, such as analysis, synthesis, generalization, comparison, induction, and deduction. Mathematic methods were used to process the empirical data. Some graphic methods were applied for schemes, diagrams, and tables. The use of a simulation method enabled to offer e-textbooks development models to Ukrainian publishers. The descriptive method was useful at the stage of describing the research results.

3 Results and discussion

3.1 E-textbooks release statistics for 2018-2019 by publishers, grades and subjects

Developing of e-textbooks for schoolchildren in Ukraine is a new phenomenon that only began its development in 2018. Our study focuses on the analysis of e-textbooks for general secondary education institutions created by national developers at the request of the state over the last two years and submitted to the committees of the Scientific and Methodological Council of the Ministry of Education and Science of Ukraine.

According to the Ukrainian legislation, all e-textbooks have to be examined and considered by the relevant subject commissions and the technical one in order to obtain the permission for use in educational process, the approval of the Ministry of Education and Science of Ukraine. The subject commissions consider the content of e-textbooks for its compliance with the requirements for the content of e-textbook and the organization of educational material of e-textbook. The technical commission

examines the compliance of e-textbooks with design ergonomic, technical requirements, the quality of their functioning, etc. All requirements for e-textbooks are set out in the Regulations on an e-textbook.

Having reviewed the development of e-textbooks in Ukraine it can be said about the increase in interest of publishers to this issue. So, in 2018 only five Ukrainian publishing houses (Alaton, Geneza, Osvita, Orion, Ranok) developed thirteen e-textbooks for the 1st, 5th, 10th grades. Last year, nine publishers worked on the development of e-textbooks and produced another 33 new e-textbooks in different subjects for students of the 1st, 2nd, 5th, 6th, 10th and 11th grades (Fig. 1).

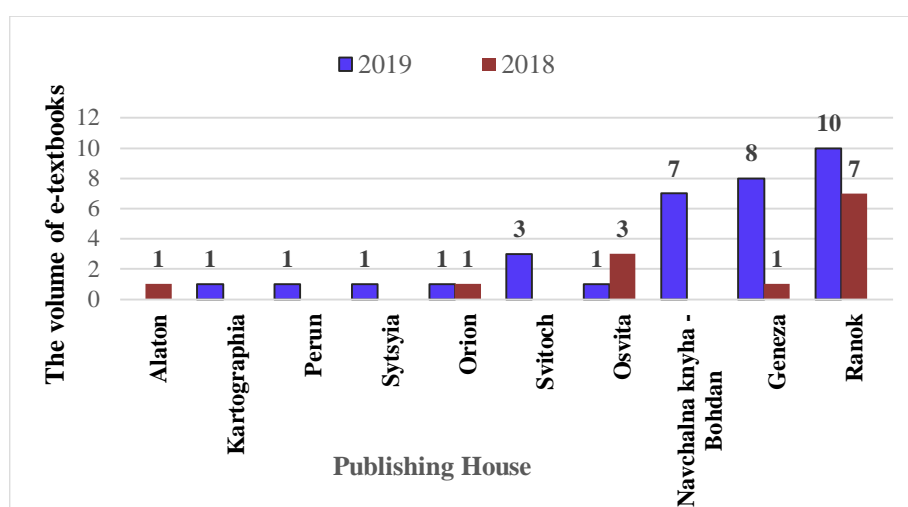


Fig. 1. Volume of e-textbooks, developed by Ukrainian publishers in 2018 and 2019.

The largest number of e-textbooks for schoolchildren was developed for the 1st grade students (19 e-textbooks), the e-textbooks for the 2nd grade were on the second place (8 e-textbooks), on the third place are e-textbooks for the 5th grade (7 e-textbooks) and 6th grade (7 e-textbooks), the last places were occupied by e-textbooks for students of the 10th (3 e-textbooks) and 11th (2 e-textbooks) grades (Fig. 2, Fig. 3).

The study showed that the publishers presented a wide selection of e-textbooks for primary school students in such subjects as “I explore the world” (7 e-textbooks) and “Mathematics” (5 e-textbooks) for the 1st grade, “Art” (8 e-textbooks) for the 1st and 2nd grades (Fig. 2).

Fewer e-textbooks, compared to primary school, were designed for middle and high school. The publishers offered 14 e-textbooks for middle school and only 5 e-textbooks for high school students (Fig. 3).

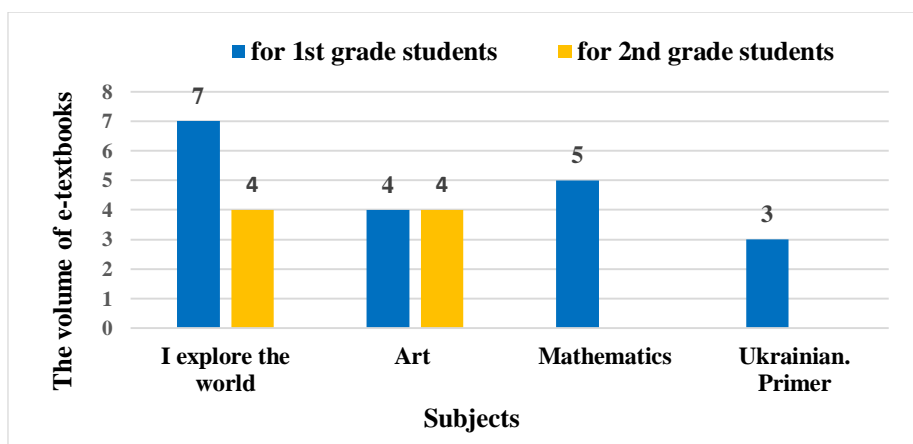


Fig. 2. Number of e-textbooks for primary school by subjects and grades.

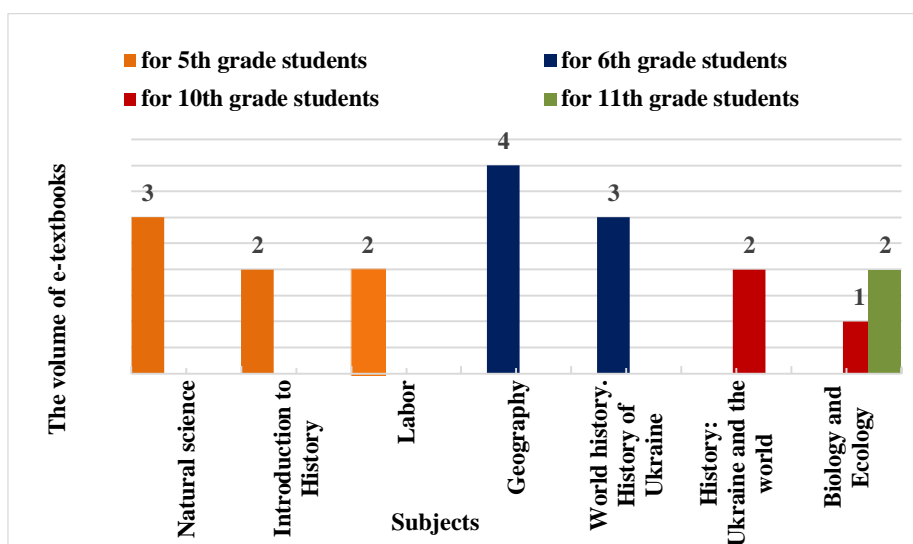


Fig. 3. Number of e-textbooks for middle and high school by subjects and grades.

3.2 Models of development of e-textbooks in Ukraine

According to the results of the survey conducted by M. Zhenchenko in 2018 on the trends in digital publishing (136 respondents), the executives of Ukrainian publishing houses indicated the lack of available software for creating interactive multimedia publications (15.5% of respondents) among the main problems hindering the development of digital publishing [12]. Because of this, the development of multimedia interactive publications is often the result of the convergence of publishing industry and IT technology sector. Software developers provide software engineers and

their experience in creating electronic products, and publishers provide content and understanding for the target audience [13, p. 300].

The study of publishing preparation technologies for 46 e-textbooks developed in 2018–2019 by Ukrainian publishers helped to clarify, and highlight the following trends:

- transfer of e-textbooks development features to other publishers or IT companies (**outsourcing model**);
- independent development of e-textbooks by publishers based on their own or third-party software (**standalone model**) (Fig. 4).

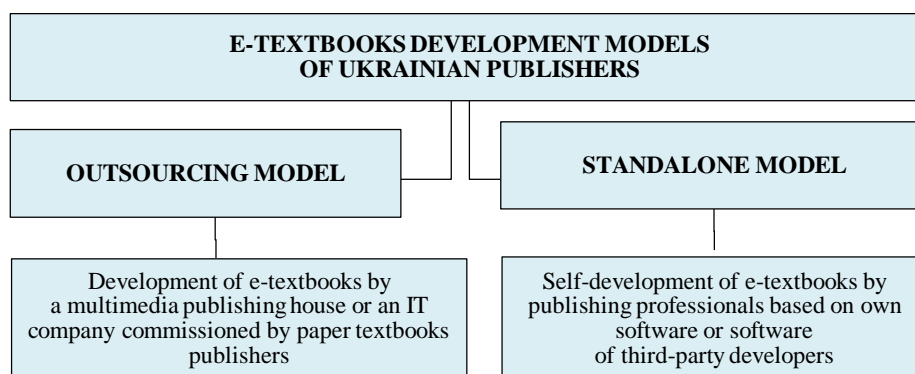


Fig. 4. E-textbooks development models using by Ukrainian publishers.

1. **Outsourcing model.** Some publishers developed their e-textbooks with the help of other multimedia publishing companies or IT companies using this model. For example, the e-textbooks of the Geneza Publishing House “Art” (1st and 2nd grades), “I explore the world” (1st grade), “Natural science” (5th grade), and “Geography” (6th grade) were developed with the help of
2. the Bristar Art Studio, which specializes in creating educational games that “cover different subjects and ages”. The textbooks contain the full text of the paper version of the Geneza Publishing House textbooks but are complemented by interactive and multimedia content, as well as a mechanism for controlling knowledge of the topic being studied. Students have the option to download the versions for Windows and Android [10, p. 44].

The Rozumnyky Multimedia Publishing House has created the e-textbooks in which the drawings “come to life” and become animated, and the characters, voiced by professional actors, tell interesting stories. These e-textbooks based on the paper textbooks from the Alaton, Osvita, Orion, Perun, Ranok, Svitoch, Sytsyia publishers. The e-textbooks contain interactive tasks that facilitate the process of information assimilation. Each task in the publications is a mini-game on a topic that students learn. If a student completes the task correctly, an owl will be hatched out an egg. The e-textbook program remembers the answers, and a teacher can see the results of the whole class in his e-journal [14]. The project team of a technology company or multimedia publishing company, which includes design artists, programmers, sound engineers and other specialists with non-publishing competencies, is working on the

creation of e-textbooks.

With this model of work, a paper textbook editor is a mediator between an authoring team, an expert and methodological circles, and a software development team. A publisher of paper textbooks may be a textbook consultant, but an IT company determines the objects of digitization on its own. The authors of the textbook are engaged in the creation of methodological support for interactive elements.

The Orion Publishing House collaborated with the Rozumnyky to create the e-textbooks “Introduction to History”, “World history. History of Ukraine” (5th, 6th grades) on the principle mentioned above.

2. Standalone model. The publishers Navchalna knyha – Bohdan and Ranok have chosen to use the third-party software to create their e-textbooks.

The Publishing House Navchalna knyha — Bohdan developed e-textbooks using the iLesson system created by the Ternopil Multimedia Publishing House Soroka Biloboka. The system enables the development of multimedia applications that work on personal computers, tablets, smartphones, includes the ability to encrypt content, provide access through short serial numbers that can be sent via e-mail or SMS, send students’ progress in a virtual classroom, view the results through free software on parent’s and teacher’s devices.

The Publishing House Ranok developed its e-textbooks in the mozaBook Editor program from Hungarian company Mozaik, which has been specializing in digital educational technologies for over 11 years. MozaBook lets you open PDF documents and creates e-textbooks based on printed textbooks with the help of a media library of the program that has over 1,200 interactive 3D models, hundreds of educational videos, a large number of audio files and interactive tasks. The mozaBook software, embedded applications, educational videos, interactive 3D models and their voices are available in lots of languages, including Ukrainian [15]. Note, that using the mozaBook does not mean an automatic transformation of a pdf file, ready for printing, into a digital multimedia textbook. According to the experts of the Publishing House Ranok, “the work volumes are enormous. Most of the content will have to be redesigned as it was designed for a print format. The texts of the printed books provided for interaction with a child without interactive tasks and equipment. That’s why the first editors will work with literature and then technicians [16]. The head of e-books department of this publishing house Yevgeniya Kovaleva emphasizes that creation of an e-textbook also requires considerable efforts from authors, who have to think how to “integrate” various test tasks, games into a textbook, so as not to disrupt the general logic of presentation of educational material [16].

The Kartographia and Geneza developed the e-textbooks based on their software. The publisher Kartographia has created its own digital platform for learning anywhere, anytime, as students and teachers can access e-textbooks with animated illustrations, voices, testing from any digital devices and any time. The Publishing House Geneza developed the e-textbook “Mathematics” for the 1st grade and “I explore the world” for the 2nd grade by creating an enriched PDF file with built-in interactive and multimedia elements. This approach enables the development of e-textbooks in Adobe InDesign, which is traditionally used for printing paper textbooks.

The summarized data in Table 1 show that 19 from 46 e-textbooks were developed using an outsourcing model, 14 of them were developed by the Multimedia Publishing House Rozumnyky.

A standalone model was used to develop 27 e-textbooks, 14 of which were developed by the Publishing House Ranok using software of the Hungarian company Mozaik Education.

Some publishers (Geneza, Ranok) used different e-textbooks development models at the same time (Table 1), which demonstrates a search of optimal production models for e-textbooks publishers, effective software for e-textbooks development and a user-friendly technology platform.

Table 1. Use of different e-textbooks development models by Ukrainian publishers.

Publishing House	Number of e-textbooks	Platform developer	Model of development
Osvita	4		
Svitoch	3		
Orion	2	Multimedia	
Ranok	2	Publishing House	Outsourcing Model
Alaton	1	Rozumnyky	
Sytsyia	1		
Perun	1		
Geneza	5	Bristar Art Studio	
Ranok	15	MozaBook Editor program of the Hungarian company Mozaik Education	
Navchalna knyha – Bohdan	7	iLesson software from the Multimedia Publishing House Soroka Biloboka	Standalone Model
Geneza	4	Enriched pdf	
Kartographia	1	Own software	

3.3 Accordance of the quality of Ukrainian e-textbooks with the national and international standards

According to the Ukrainian legislation, all e-textbooks have to be examined and considered by the relevant subject commissions and the technical one to get the conclusion “Recommended by the Ministry of Education and Science of Ukraine”, which gives the right to use the e-textbooks outside one educational institution. The subject commissions consider the content of e-textbooks and the organization of educational

material in e-textbooks, the technical commission examines the compliance of e-textbooks with design ergonomic, technical requirements and the quality of their functioning. All requirements for e-textbooks are set out in the Regulations on an e-textbook.

The important technical and functional requirements for e-textbooks are:

- the ability to “enable the operation of three or more operating systems, at least two of which are for mobile devices”;
- the presence of “means of navigation by its structural units (eg, content, subject index, name index, etc.); tools for working with text, including the ability to take notes, bookmarks, highlight text, print selected pieces of training material in text or image format, the ability to search for keywords, as well as a dictionary (dictionaries); interactive elements”;
- “balanced ratio of multimedia and other content” [1, p. 4].

However, not all 46 developed e-textbooks got the conclusion “Recommended by the Ministry of Education and Science of Ukraine”, half of them did not pass the subject and/or technical commissions and was rejected because they don’t meet requirements indicated in the Regulations on an e-textbook. Only 23 from 46 developed e-textbooks for schools got the commissions’ conclusion “Recommended by the Ministry of Education and Science of Ukraine”. None of 5 e-textbooks developed for high school passed the examination of the commissions (see Fig. 5).

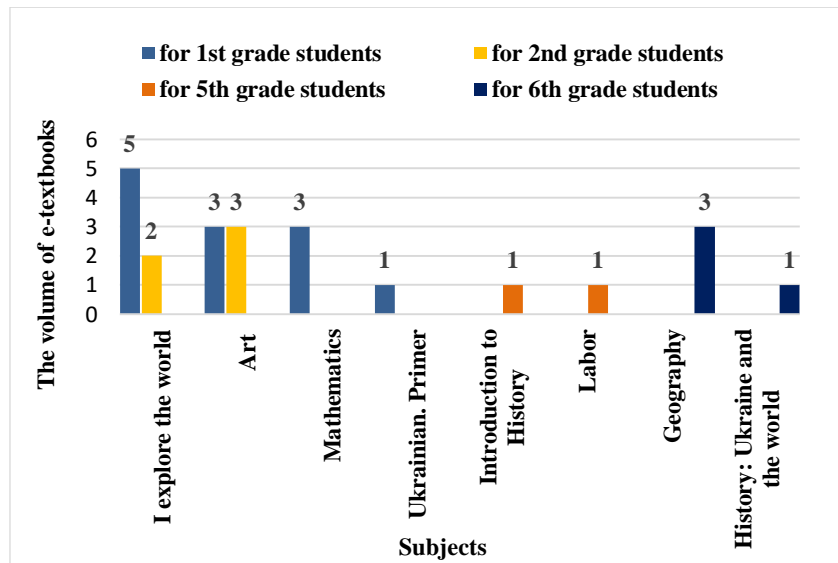


Fig. 5. Number of e-textbooks, which were approved for the use in schools.

It should be emphasized that the analyzed e-textbooks were developed on different technological platforms, there was no single unified format of e-textbooks, and most e-textbooks were designed as specialized programs for which a user needs to install additional software.

The international standard (ISO/IEC TR 18120:2018. Information technology — Learning, education, and training — Requirements for e-textbooks in education (ISO/IEC TR 18120:2016, IDT) adopted in the early 2020 in Ukraine states that “the standard provides for the need to define a common e-book format, preferably one that already has international recognition, which can be used as a basis for any specific educational specifications and standards that may be needed” [11, p. 6] and suggests that “the future standard of e-textbooks should be based on EPUB3 as the core standard, but allow extensions to handle alternative formats, if supported by certain practitioner communities” [11, p. 32]. HTML5 and XML are also mentioned as positive formats in different countries [11, p. 31].

Besides, the above standard provides an overview of pilot studies on the use of e-textbooks in different countries, the best practices of which should be taken into account in our country too.

Furthermore, the study identified some problems of developed in 2018 and 2019 e-textbooks for schoolchildren, such as their quality, absence of a single technological platform for their creation, as well as a single, acceptable for developers and users, e-textbook format, most e-textbooks require additional software.

The subject of previous research (A. Antokhova, L. Ilychuk, M. Zhenchenko) was only e-textbooks developed in 2018 for the 1st grade or justifying the use of Smart Kids technology and e-textbooks in educational process of elementary school (S. Lytvynova).

The problems of developing the e-textbooks publishers market, providing e-textbooks of various subjects and grades of secondary school, compliance of the e-textbooks' quality with the national and international standards were uninvestigated by scientists.

To solve the above problems there is a need to learn the experience of other countries in implementing e-textbooks to take into account the best practices; to conduct a thorough study of the impact of the use of e-textbooks on the level of students' educational achievements and concerning the role e-textbook in educational process; to define a clear e-textbook format adopted for developers and users; to create of accessible for Ukrainian publishers on the criterion “price-quality” technological platforms for the development of multimedia interactive e-textbooks that will meet the requirements of international standards and promote the development of blended and distant learning technologies. This will help to improve e-textbooks' quality and understand their role in the education process.

4 Conclusion

Ukraine is only making the first steps towards the digitization of education. The considerable attention has been paid to the development of the legal framework recently that is the background of such changes. This, in turn, encouraged developers to create e-textbooks that meet certain requirements and criteria adopted at the state level.

The study found that the number of publishers that started developing electronic content increased from 5 in 2018 to 9 in 2019. It was identified that major players in the Ukrainian e-textbooks market is the Publishing Houses Ranok, Geneza, Navchalna knyha — Bohdan (submitted in order of reducing the number of developed e-

textbooks).

It is also revealed that the number of e-books for Ukrainian students increased significantly over the last year. If only 13 of these textbooks were developed in 2018, their number increased by 33 in 2019. Most e-textbooks were developed for students of the 1st and 2nd grades (19 and 8 respectively); the least e-textbooks were designed for students of the 10th and 11th (3 and 2 respectively) grades.

A review of all e-textbooks developed for compliance with the requirements specified in the Regulations on an e-textbook revealed that only 23 e-textbooks were recommended by the Minister of Education and Science of Ukraine for the use in the educational process, all of which were refined over the last year and sometimes more than once.

The study on the issue of e-textbooks modeling by Ukrainian publishers found that there are two e-textbooks development models in Ukraine: 1) outsourcing, used by 6 publishers, and 2) standalone, used by 2 publishers; 19 e-textbooks were produced using the first model; 27 e-textbooks were developed using the last one. Two publishers have developed e-textbooks using both models.

Most publishers have used for their e-textbooks the platform of the Multimedia Publishing House Rozumnyky (14 e-textbooks) and the mozaBook Editor program of the Hungarian company Mozaik Education (15 e-textbooks).

In general, the analysis of 46 e-textbooks showed that despite the rapid development of e-textbooks in Ukraine, there are some problems with their quality, they are prepared through different technological platforms, there is no single technological platform, as well as a single, acceptable for developers and users, e-textbook format, most e-textbooks are designed as specialized programs that require additional software.

The following is suggested to solve the above problems:

1) learning the experience of other countries in implementing e-textbooks to take into account the best practices;

2) conducting a thorough study of the impact of the use of e-textbooks on the level of students' educational achievements. Such a study will determine at the state level what e-textbook for primary, middle and high school students should be: just a supplement for a paper textbook or alternative;

3) defining a clear e-textbook format adopted for developers and users;

4) creation of accessible for Ukrainian publishers on the criterion "price-quality" technological platforms for the development of multimedia interactive e-textbooks that will meet the requirements of the international standards and promote the development of distant and blended learning technologies;

The problem that requires further study in this area is developing a mechanism for the purchase of e-textbooks by the state.

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Students Academic Achievement Assessment in Higher Education Institutions

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Abstract. Students academic achievement assessment in higher education institutions is one of the most urgent tasks that teachers face in the role of organizers of the educational process. The problem of forming a correct and objective rating point in assessing the results of studying a discipline is the key point in the final stage in studying thematic and module parts of the material. The rating score is formed by assessing individual student's educational activities. Depending on the type of assessment and control the students' vision of assessment objectivity is different.

This study analyzes the works of Ukrainian and foreign authors who have devoted their scientific research to studying the question of students' learning outcomes control and evaluation; highlighting the principles of formative assessment and the peculiarities of distance learning assessment tasks formation.

Particular attention is paid to the development of the author's methodology for educational achievements assessment for future bachelors of computer science. The contents of Bloom's taxonomy levels are discussed, as well as the explanation of the types of activities for the assessment system, for example, the design of practical tasks of the discipline "Algorithmization and Programming" (C++ programming language) of the specialty "Computer Sciences", which is being studied in the first year by future bachelors of computer sciences.

Keywords: students academic achievement assessment, Bloom's taxonomy, assessment rating system

1 Introduction

Each year in Ukraine, higher education institutions with IT-specification training prepare a sufficient number of IT branch bachelors, in particular, future bachelors of computer science who are in extreme demand in the domestic IT job market.

But there is enough evidence that only 25% of IT-specification graduates can find employment in an IT company, while other graduates do not meet the requirements which are put forward by the employers while headhunting.

Which remains important is the question of improving the quality of professional training for future bachelors of computer science, of their level of professional competence, and in particular, their IC competence, so that it could meet the IT market current requirements, global needs as well as employers' requirements [1, p.11].

Nowadays in our country there is still no single educational toolkit that allows measuring and assessing the outcomes of the learning process as well as the level of competency acquired, although there are examples of such tools on international level (for example, TIMSS, PISA, CIVIC Education Project) which Ukrainian students can use as well, if they are willing to [2, p.154].

The improvement of forms and methods aimed at creating a coherent system of continuous education allows to develop a unified system for assessing the dynamics of development motion for bachelors of computer sciences in their educational activities

2 Research Results

The following methods were used in the research process: theoretical - studying and analysis of pedagogical, methodical and scientific literature; modern scientists studies results analysis to find out the state of the problem; observational - educational process observance; praximetric - study and analysis of curricula, educational documentation, programs and results of student activities as well as research methods such as surveys, questionnaires, teacher interviews, methods of comparative analysis and statistical data processing.

Theoretical and practical issues of the assessment system organization for academic students achievements in higher education institutions are covered in the works of V.M. Bocharnikova [3], V.M. Kukharenko [8], S.G. Lytvynova [9], M.I. Tomilova, Ye.Yu. Vasilyeva, O.A. Kharkova [4], L.M. Ognevchuk [2], B.Ye. Starychenko [7] and others.

However, special attention needs to be paid to the issues of procedural, technological, motivational support for the assessment of the academic achievements of students in higher education institutions as a coherent pedagogical system that takes into account individual interests, abilities and inclinations.

3 Research Results

New technologies introduction into the educational process in higher education institutions leads to the emergence of new unconventional forms and methods of assessing the educational attainment of students in higher education institutions. In the framework of our study, we consider the research of scholars in relation to students educational achievements assessment, in particular future bachelors of computer sciences.

On one hand we can see, according to V.M. Bocharnyk the assessment, which is carried out in the course of students' educational achievements control, stimulates

them to active educational and cognitive activity, and therefore, acts as a learning factor, which determines positive results of the educational process [3, p.23].

On the other hand there is a substantial subjective part to it - M.I. Tomilova, Ye.Yu. Vasilyeva, O.A. Kharkova investigated the issues of students' perception of knowledge assessment done while realizing studying activities in higher education institutions. They came to the conclusion that students differently evaluate the objectivity and fairness of their knowledge assessment. Most students highly rate the objectivity of their knowledge assessment in an oral questionnaire or interview, but one in ten felt that the results did not correlate with the real level during tests. Most students praised the objectiveness and fairness of the point-rating scale. More than half of the students (59%) rated the degree of external factors (mood, attitude to the teacher) influence on the process [4, p.30].

Students' evaluations of the assessment they get are not the only thing that diverges, but also the system of assessment making itself as well.

Foreign authors S.A. Borodich, A.N. Teplyakovskaya, comparing the problems and perspectives of the point-rating system (PRS) of student knowledge assessment at universities in Russia and Belarus, conclude that in Belarus PRS is practiced only as a system of ten-point rating basis and only in face-to-face classroom education. Russian universities adopted a PRS of maximum points in a discipline of 100 points. These are scored for: intermediate attestation (credit or examination) - 40 points and other 60 points are achieved by the student during current and boundary control of knowledge build up during the semester educational process [5, p.139]. It is worth while noting that in the first year at university students have different starting points due to different conditions of studying in schools and the divergences of goals of educational process subjects.

Ukrainian higher education institutions have also adopted the system of 100 points rating for the students' achievements in one discipline. An example of this is the provision on the rating system for evaluating the learning outcomes of NTUU "I. Sikorsky Kyiv Polytechnic Institute" [6].

B.Ye. Starichenko, a Ukrainian expert, proves that obtaining a disciplinary rating score is possible and that its basis is the evaluation of all separate student's educational activities, provided by the discipline study plan. After calculating the average share of performance across all activities, it is reduced to a 100-point scale, which is a disciplinary rating [7, p.205].

A system for evaluating the educational achievements of higher education institution students based on a competency-based approach was proposed by L.M. Ognivchuk in her works. She also observed the fact that in other countries experts traditionally identify three main approaches to defining and putting into practice a competence interpretation to the quality of learning outcomes: a behavioral approach (USA), a functional approach (UK) and a multidimensional and holistic approach (France and Germany). These approaches appeared independently from each other first in the United States, then in the United Kingdom, and most recently in France and Germany [2, p.155].

A many year research into the issues of distance learning technologies introduction brought V.M. Kukharenko to the conclusion that at this stage of development of scientific approaches to students' academic achievement assessment, special attention has to be paid to the formative assessment which was adopted [8, p.53].

Another Ukrainian researcher S.G. Litvinova agrees with V.M. Kukharenko. In her work she notes that it is possible to increase the efficiency of control and assessment of students' knowledge with the help of formative assessment. In the present study we agree with her view that formative assessment is used by teachers to obtain data on the current state of students knowledge level in a particular topic as well as to identify next steps that should be taken to improve them [9, p.112].

The authors of this research clearly believe that benchmarking is needed for successful assessment organization as well as points that will allow evaluating the assessment system itself working properly.

Periodicity, educational and cognitive activity motivation, as well as individualization and differentiation can be seen as indicators of the didactic effectiveness of educational achievement formative assessment.

The peculiarities of formative assessment lie in the fact that it is student's strive in realization of his/her educational goals, which is assessed but not his / her personality. A clear algorithm for determining the grade is offered, which is more understandable for the student; the focus is on the student's personal progress rather than the assessment. The following forms of students progress formative assessment of are offered: reflexive techniques (hand signals, card signals) to clarify and identify complex issues; clarifying questions; analytical questions; mini-tests; checking creative work for error detection etc. [9, p.112]. Among the features are: training, stimulating, controlling.

Considering the positive experience of the teachers of the National Technical University "Kharkiv Polytechnic Institute", in particular V.M. Kukharenko, in conducting an experiment on the use of Bloom's taxonomy to evaluate students' academic achievement, we will apply this approach to develop authors' methodology for evaluating academic achievement of future bachelors of computer science.

The authors of this article would like to point out that this approach is the basis for the control and assessment unit of the model of professional competence formation for future bachelors of computer science. Programming students knowledge level assessment is carried out using Bloom's taxonomy, which contains 6 levels of difficulty. Each practical task will correspond to its level with a certain number of points [10, p.110].

What should be taken into consideration when forming this model's control unit is that the employers put high requirements to employees, and the level of knowledge and skills of the graduates does not meet these requirements, as their education has mostly theoretical nature. This, in turn, requires constant correction of curricula and subjects taught in higher education institutions, as well as regular personnel retraining [11, p.85].

While assessing the knowledge level, substantial attention is paid to monitoring the work results of future bachelors of computer science, as an integral part of educational process, which is aimed at providing "student-teacher" feedback and to identify the basis of its correct organization [12, p.10].

Tasks formation of is carried out in accordance with the spheres of cognitive (Cognitive Domain), emotional (Affective Domain) and motor (Psychomotor Domain) goals. Cognitive goals cover everything related to knowledge acquisition and mental skills development. Emotional goals include all tasks related to values formation, relationships, students' emotional self-control development. Motor goals embrace motor skills development, as well as physical endurance [13, p.89], [14], [15].

While drawing up practical tasks, particular attention is paid to the field of cognitive goals, which is divided into the following six levels:

1. Remembering (Knowledge Level) – lower level.
2. Understanding (Comprehension Level).
3. Implementation (Application Level).
4. Analyzing (Analysis Level).
5. Assessment (Synthesis Level).
6. Creation (Evaluation Level) – higher level.

This is a classification of thinking, which is organized according to complexity levels and gives teachers and students the opportunity to learn and act in informational and educational space, provides a simple structure for many types of questions [13, p.98].

For example, we consider the content of Bloom's taxonomy levels with the definition of activity (verbal form) for designing practical tasks of the discipline "Algorithmization and Programming" (C++ programming language) specialty "Computer Sciences", which is studied in the first year by future bachelors of computer Sciences (Table 1).

Table 1. The content of student's activity (verbal form) during practical tasks realization according to Bloom's taxonomy

Bloom's taxonomy levels	Level Contents	Definition of student activity (verbal form)
Remembering Level (Level 1)	All entry-level goals are formulated in practical reproduction examples. It is enough to acquaint students with theory and relevant practical examples so that they can repeat it in their programs	Show, characterize, adhere to a code design standard (coding standard, programming style), program code lines explanation by means of a comment
Understanding Level (Level 2)	In order to demonstrate the practical achievements of the understanding level (comprehension), programmer students have to: <ul style="list-style-type: none"> – draw up a block diagram of a simple task algorithm; – implement the algorithm in the form of a program code (compilation without errors); – apply the acquired knowledge in the program code into specific simple tasks (information is remembered and processed individually). 	Compile, implement, describe, explain, anticipate, define, evaluate, adhere to the standard of code design (coding standard, programming style). Explain code lines using the comment

<p>Implementation Level (Level 3)</p>	<p>In the Implementation level a student-programmer must fully demonstrate practical achievement of the Comprehension Level (Level 2). In addition, solve, execute and display a program code with advanced levels of complexity and functionality of previous-level practical tasks</p>	<p>Apply, demonstrate, count, execute, illustrate, show, solve, test</p>
<p>Analyzing Level (Level 4).</p>	<p>The goals of the Analyzing level (analysis) assume that programming students are able to:</p> <ul style="list-style-type: none"> – analyze the task; – perform decomposition of the task (partitioning into separate simple tasks); – draw up a general flow chart of the algorithm and sub-task flow charts based on decomposition; – implement the algorithm of complex practical tasks in the form of a program code using functions 	<p>Analyze, decompose Execute complex practical tasks algorithm (write a program code)</p>
<p>Assessment Level (Level 5)</p>	<p>At the level of synthesis (assessment), students-programmers must fully demonstrate practical achievements of the Analyzing level (level 4). In doing so, solve, execute and display program code with increased levels of complexity and functionality of previous level practical tasks</p>	<p>Combine, integrate, modify, reposition, replace, plan, create, design, invent, anticipate (what if?), assemble, formulate, prepare, generalize, rewrite</p>
<p>Creation Level (Level 6)</p>	<p>At the sixth level, programming students demonstrate:</p> <ul style="list-style-type: none"> – application of the studied material as a tool in solving complex problems of different directions (logical, mathematical, physical, metric, etc.) – performing the decomposition of the task (partitioning into separate simple tasks), 	<p>Evaluate, decide, classify, sort, control, measure, recommend, persuade (assure), select (select), judge (evaluate), explain, distinguish (recognize), support, conclude (finish), compare (compel), summarize.</p>

	<ul style="list-style-type: none"> – drawing up a general flow chart of the algorithm and a flow chart of the subtasks, – application of the first paradigm of object-oriented approach - encapsulation (presentation of the program code in the form of 2 separate files: interface file (.h-file) and implementation file (. spp-file)) – algorithm implementation with the use of functions 	
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The authors offer an educational achievements assessment rating system using Bloom's taxonomy levels which is represented in Table 2.

Table 2. Student educational achievements rating system using Bloom's taxonomy levels

Levels	Levels by Bloom's Taxonomy	Rating	Credits ECTS	Credits ECTS
6	Creation	95-100	A	perfect
5	Assessment	85-95	B	very good
4	Analysis	75-85	C	good
3	Implementation	70-75	D	very satisfactory
2	Understanding	65-70	Dx	satisfactory
1	Remembering	60-65	E	sufficient

In addition, each level of Bloom's taxonomy is subdivided into the following sub-levels: practical assignment accomplishment and defence, practical assignment accomplishment quality, term of delay (deadline non-meeting) for a practical assignment accomplishment.

The score of each sub-level may be reduced / increased. In order to determine the percentage reduction / increase in the resultant evaluation of each sub-item, a survey was conducted with 76 teachers from 23 regions of Ukraine and the city of Kyiv participating.

The results of the survey, namely the percentage reduction in the resultant evaluation of each sub-level, are presented in the form of diagrams and are shown as follows: practical assignment accomplishment - Fig.1, practical assignment accomplishment defence - Fig.2, the term of delay (deadline non-meeting) for a practical assignment accomplishment - Fig.3.

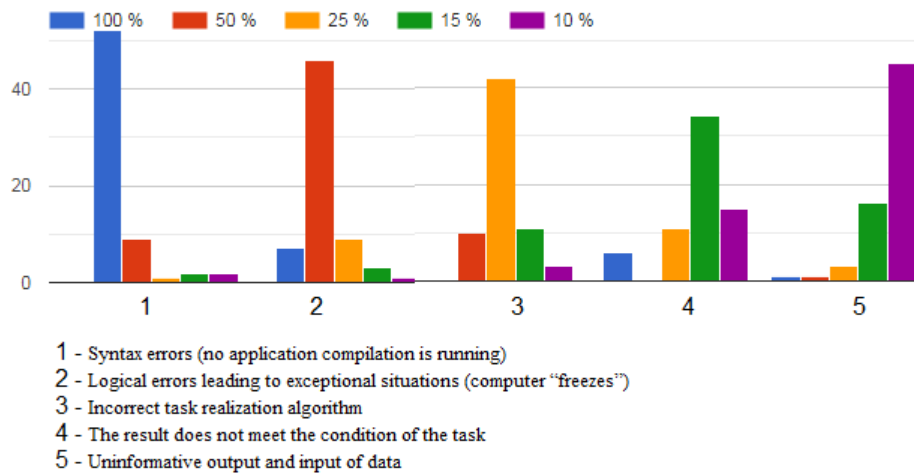


Fig. 1. Practical assignment accomplishment

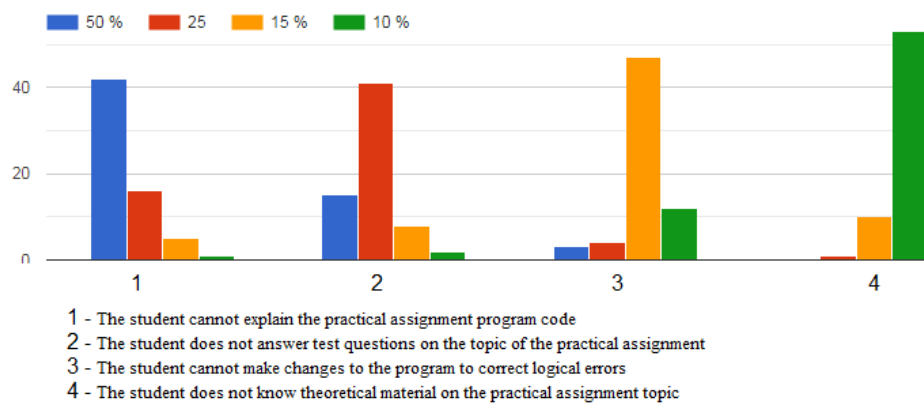


Fig. 2. Practical tasks defence

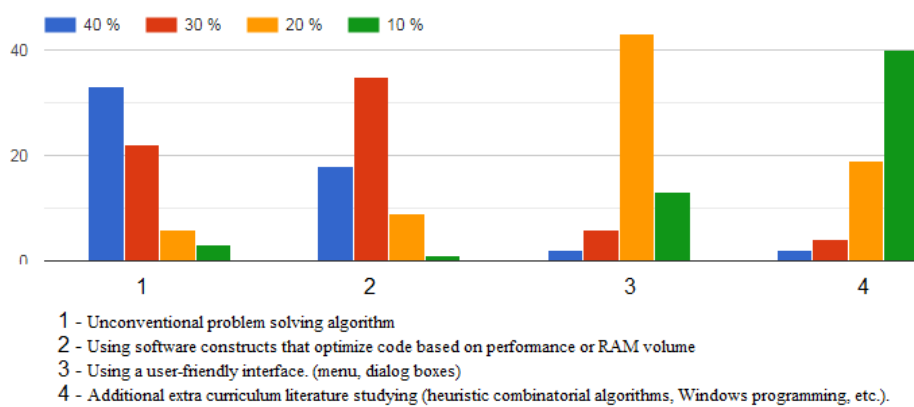


Fig. 3. Practical assignment accomplishment quality

For convenience, all these results are summarized in Tables 3, 4.

Table 3. Rating reduction percentages for practical assignments accomplishment

1. Practical assignment accomplishment		
№	Error type	% reduction
1	Syntax errors (no application compilation is running)	100
2	Logical errors leading to exceptional situations (computer “freezes”)	50
3	Incorrect task realization algorithm	25
4	The result does not meet the condition of the task	15
5	Uninformative output and input of data	10
Total		100
2. Practical tasks defence		
№	Error type	% reduction
1	The student cannot explain the practical assignment program code	50
2	The student does not answer test questions on the topic of the practical assignment	25
3	The student cannot make changes to the program to correct logical errors	15
4	The student does not know theoretical material on the practical assignment topic	10
Total		100
3. The term of deadline non-meeting		
№	Delay period	% reduction
1	Two weeks	10
2	Two weeks to four weeks (month)	20
3	Four weeks to six weeks	35
4	Six weeks to eight weeks (two months)	50
5	Eight weeks to 12 weeks	70
6	More than 12 weeks	80

Table 4. Rating reduction percentages for practical assignments accomplishment

Practical assignment accomplishment quality		
№	Non-standard approach type	% reduction
1	Unconventional problem solving algorithm	40
2	Using software constructs that optimize code based on performance or RAM volume	30
3	Using a user-friendly interface. (menu, dialog boxes)	20
4	Additional extra curriculum literature studying (heuristic combinatorial algorithms, Windows programming, etc.).	10
Total		100

Let us study an example of practical assignments accomplishment assessment making for a practical assignment accomplished by a student. The percentages of each decrease for practical assignments accomplishment component are summarized in Table 5. All percentages of decrease for practical assignments accomplishment obtained are summed up.

Table 5. All percentages of decrease for practical assignments accomplishment obtained are summed up.

	Rating planned	% reduction	% increase	Rating total
1. Practical task accomplishment		25		
2. Practical task accomplishment defence		0		
3. Practical task accomplishment report		10		
4. Practical task accomplishment quality			0	
5. Practical task accomplishment delay		0		
Total :		35%		
for level 6	100			65,00
for level 5	95			61,75
for level 4	85			55,25
for level 3	75			48,75
for level 2	70			45,50
for level 1	65			42,25

In other words, for example, a student chooses a practical assignment that corresponds to the sixth level, which maximum score equals 100. Supposing the student receives a 25% reduction for task implementation incorrect algorithm in the section " Practical assignment accomplishment" and - 10% for the inability to answer test questions on the topic of the practical task in the section " Practical assignment defence ". The reduction percentages are added up. The final rating points reduction depends on the total summed up reduction percentages (see Table 5). There is a possibility that the students can improve their results as well. For example, if in the "Practical task accomplishment quality" section the student received a percentage increase - the final score will be increased by the amount of that percentage.

Thus, this technique can be used to evaluate students' academic achievement using Bloom's taxonomy levels in any discipline

4 Conclusions

The present research analyzes works of Ukrainian and foreign authors on the issues of control and educational activity results assessment while working with students in higher education institutions. The principles of formative assessment and the levels of cognitive, emotional and motor goals are highlighted in the article.

Authors' technique for educational activity results assessment for future bachelors of computer sciences, which combines Bloom's taxonomy and the classical scoring system for students' knowledge assessment and makes it possible to implement differentiated and individual approaches and build an individual trajectory of each student's development.

The authors substantiate the content of Bloom's taxonomy levels, explain the types of activities for the assessment system on the example of designing practical tasks of the discipline "Algorithmization and programming" gives the teacher a new methodology and a new tool for assessing student achievement.

This technique, thanks to the use of Bloom's taxonomy, will enable the teachers to determine the level of competence of the student at intermediate stages of learning. Solving problems of a certain grade correctly, partially or not solving at all - the student realizes his level of knowledge.

The disadvantages include the fact that for this technique the teacher needs a large amount of time to create a set of methodological support for specialties.

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Attitude of Ukrainian Educators toward the Use of Digital Tools for Teaching and Professional Development: Survey Results

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Abstract. The article deals with the results of the survey of the attitude of Ukrainian educators toward the use of the digital tools for teaching and professional development conducted by the Comparative Studies Department for Information and Education Innovations of the Institute of Information technologies and Learning Tools of the NAES of Ukraine in 2019. 178 respondents – teachers, school administrators, methodologists and in-service teacher training professors answered on the questionnaire from all-over Ukraine. The content of the study covered the following topics: Internet access on the workplace; professional activities and the use of ICT; using ICT tools in the classroom work and professional development; social networks; cloud services; electronic systems of the educational process management and organization; self-assessment of the level of the digital/ information and communication competence; suggestions and attitudes toward the use of ICT for the professional development and practical work. The answers of the respondents allowed providing proposals on the use of digital tools by teachers in their professional activity. The purpose of the article was to present the survey results and provide suggestions on the professional development of teachers and the assessment of their digital competence.

Keywords: Teachers; Educators; Professional Development; Training; Attitude; Survey; In-Service System; ICT Tools.

1 Introduction

Problem statements. Today, in a period of rapid technological development, its impact on the economy, politics, education and daily life, the ability of a person to use digital media, communicate and navigate the Internet, social media, know and use their potential is important. Teachers are the main actors in the education sphere related to the development of the new generation as individuals able to build a successful life trajectory. One of the main factors in the process of education is the use of the digital technologies, in particular the use of the digital tools by the teachers for transferring knowledge to their students and developing their competencies. According to the New Ukrainian School Concept the modern teacher should be motivated, able to build

partnership and works in a team, provides training and support for the students, is able to learn all over the life. Moreover the teacher of the New Ukrainian School should be able to create the collaborative environment with other colleagues, students and community, and has a proficient level of the digital competence [1]. All these features of the teachers are in the scope of the Ukrainian scholars, policy makers and stakeholders. The attitude of teachers to the new technologies and their use in the teaching process reveals the level of teachers' digital competence.

The study conducted by the Department of the Comparative Studies for Educational Innovations of the Institute of Information Technologies and Learning Tools of the NAES of Ukraine in 2019 was aimed at the investigation of the teachers' attitude towards the use of the digital tools, in particular, digital teaching and learning platforms, social media, and digital devices for different purposes in the process of teaching and professional development. It allowed indentifying gaps in the sphere of in-service teacher training in terms of their professional development regarding ICT. The results of the study allowed formulating recommendations for the institutions conducting training for teachers, school heads on how they can use ICT in teaching subjects, organizing extracurricular activities, and for their personal professional development.

2 Literature Review

The foundations of the ICT use by teachers are grounded in the works of domestic scientists and practitioners V.Y.Bykov, V.V.Oliinyk, O.Yu. Burov, V.I. Lugovy, O.M.Spirin and others. The scientists stress mainly on the general approaches to the ICT use by professionals, their ICT-competence, pedagogical conditions and digital environment that should be created in the pedagogical and in-service teacher training institutions for teachers' development regarding ICT [2]. The mentioned authors have made a significant contribution to the development of scientific and methodological support for the training and advanced training of computer science teachers and for its study in other subjects, in particular by distance form; creation of new training systems and cloud-oriented educational environments, electronic educational resources, electronic scientific professional publications, textbooks and manuals for different levels of education.

The approaches to the use of the cloud based and e-based learning tools are revealed in the works of M.P.Shyshkina, S.G.Lytvynova, N.V.Soroko, O.V.Ovcharuk, O.O.Gritsenchuk, I.D.Malicka, I.V.Ivaniuk and others [3; 4; 5; 6]. These researchers investigate forms and methods used by teachers in the process of the development of the digital learning and teaching environment in educational institutions from the comparative perspective.

The purpose of the article is to reveal the teachers' attitude towards the use of digital tools for the teaching and professional development through the conducted in 2019 survey, and to formulate the proposals for the system of in-service teacher training concerning overcoming obstacles and gaps in teachers' professional development.

3 Research Methods

A systematic approach to information retrieval, phenomenon study, the data gathering about the attitude of teachers towards the ICT tools use were applied. Particular importance was given to the analysis, synthesis of information based on common scientific methods of analysis and synthesis. In addition, computational methods of information processing were applied during the data processing survey. Questionnaire was based on European documents, including the Digital Competence Framework for Educators (2017) [7].

4 Research Results

Recent trends in the field of digital technologies are related to such concepts of the modern world as, digital citizenship, digital consumers, digital governance, e-commerce, cyber security, Internet of things, Internet of toys, etc. In the context of these challenges, teachers should prepare young people to be confident in their digital competence and direct them towards their own development. The need to make changes in teaching method and approached is revealed in the newly adopted Law on Education (2017) and New Ukrainian School Concept (2016) [1]. The Law on Education states that everyone has the right to access public educational, scientific and information resources, including the Internet, electronic textbooks and other multimedia educational resources in the manner prescribed by law [8].

The first problem noted in the Concept of New Ukrainian School is the that the most successful in the labor market in the near future will be professionals who are able to learn all over the life, think critically, set goals and achieve them, work in a team, communicate in a multicultural environment and have other modern skills. But the Ukrainian school is not preparing for this.

The second problem is that like 10, 20, 50 years ago, the average Ukrainian student acquires obsolete knowledge at school. In recent years, this volume has increased tremendously, as has the overall global information flow increased in the world. Students are only able to reproduce fragments of unsystematic knowledge, but are often unable to use them to solve life's problems.

Teachers use mostly outdated didactic tools. The digital gap between teacher and student is widening. Many educators do not yet know how to research problems using modern digital tools, work with large data basis, draw and present conclusions, collaborate online in educational, social and scientific projects. All these above mentioned issues were proved by the survey conducted. Let's take a closer look at this study.

Thus, the survey was conducted in 2019 in the framework of the study "Development of information and communication competence of teachers in a cloud-oriented learning environment" (registration # 0117U000198). It was gathered 178 respondents, all responses were anonymous. The survey was constructed on the base of the Google Forms [9]. It consists of nine parts and 18 questions. The main parts are:

1. General information about person (work experience, age, status of institution, gender etc.);
2. Internet access on the workplace;
3. Professional activities and the use of ICT;
4. Using ICT tools in the classroom work and professional development;
5. Social networks;
6. Cloud services;
7. Electronic systems of the educational process management and organization;
8. Self assessment of the level of the digital/ information and communication competence;
9. Suggestions and attitudes toward the use of ICT for the professional development and practical work.

The first section of the survey compiled respondents' personal data. The most part of the respondents were from 26 up to 40 years old (48,3%) and from 41 up to 55 years old (34,3%). Less respondents were 55 and more years old (14%) and less 25 (3,4%), (Fig.1).

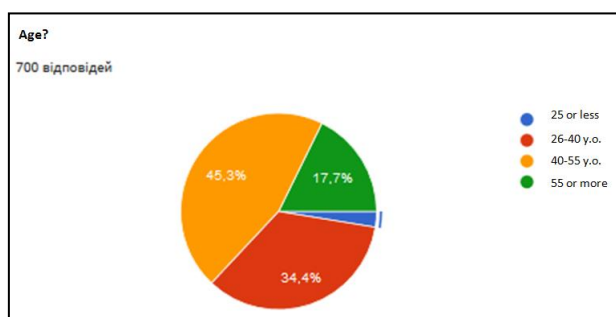


Fig.1. View of the diagram about the diversity of the age of the respondents.

The next question in the first section of the survey concerned the type of respondents' professional activity. The answers were distributed as follows: school administrators (school heads and their deputies) – 11,2%; professors in the in-service teacher training institutes – 16,3%; teachers – 71,9%; scientists in the sphere of pedagogic – 3,9%; methodologists – 4,5% and others.

The following questions were answered on the professional experience record: up to 5 years – 7,3%; up to 10 years – 20,2%; up to 20 years – 32,6%; 20 years and more -39,9 %.

The gender distribution was 75,35% – female; 24,7% - male respondents.

The second section concerned the Internet access on the workplace. 88,8% respondents have sufficient access to the Internet and 10,7% - insufficient, 0,6% does not have any.

The next question in this section was on how many time the respondents spend in the Internet and for which purpose (for professional and personal purposes). The diagram below shows the distribution of the time in the Internet (Fig.2).

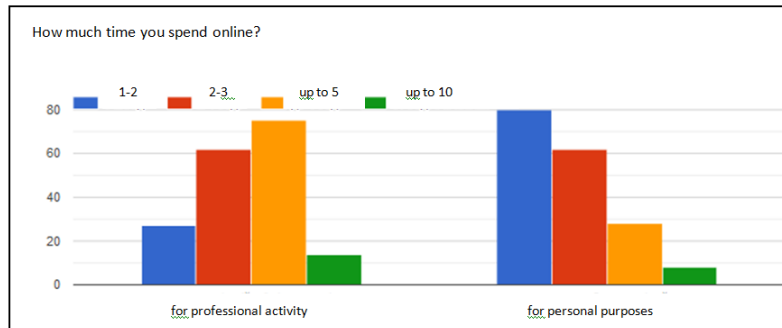


Fig.2. The diagram about the distribution of the time of the respondents spent in the Internet for the professional and personal purposes daily (the vertical scale shows percentages, the columns are distributed by colors: blue – 1-2 hours; red – 2-3 hours; yellow – up to 5 hours; green – 10 and more hours).

The left part of the diagram on the Fig 2 is about professional activity, and the right part is on the personal purposes. As we can see on the diagram, up to 80% of educators spend up to 5 hours daily for the professional purposes. The next question on this section was: What search engines (browsers) do you use to get the necessary online educational resources? 99,4% use Google. Other 0,6% use Yahoo, Ukmet, Bing and others.

One of the important question of the survey was about how do the respondents check the credibility of online learning resources and digital tools. The responses were the following:

- I use only official and well-known websites in professional environment - 71,3%;
- I pay attention to the authors of the resources and the presence of references – 61,8%;
- I pay attention to the content of the source, the structure, the presence of hyperlinks and navigation – 50,6%;
- I check through the top ranked resource on Google, and also pay attention to the URL, for example: gov; edu; com; org. – 43,8%;
- I avoid spam and mailing – 64%;
- I don't check because I don't know how – 1,7%.

In this case respondents could highlight (mark) one or more proposed options.

The next sections of the survey concerned the details of the use of digital learning tools, social networks and cloud computing in the professional activities.

The third section is devoted to the use of the ICT in the professional activity of educators. The question was: for what purposes do you need information and communication technologies and digital tools in your professional activity? The answers distributed as follows:

- searching for information and educational resources – 93,3%;
- creation and use of audio and video material in lessons / professional activity – 71,9%;
- creating/using didactic materials and learning, to create learning games – 66,9%;
- creating and maintaining a personal Web site, blog - 46,1%;
- implementation of distance learning – 48,9%;
- virtual lab work – 15,2%;

- lesson planning and design – 53,4%;
- creating online questionnaires and tests - 53,4%;
- self education and personal development, scientific research and other – 0,6%.

Section four contains the question about what kind of ICT tools pedagogues use in their professional activities. The answers were the following:

- personal computer – 89,3%;
- notebook -75,3%;
- Smart Board – 18%;
- Smart Phone – 69,1%;
- Tablet – 28,1%;
- Multimedia projector, TV – 0,6%.

The fifth section is about what social networks do the teachers and other educators use. The diagram on the Fig.3 show that the majority of respondents use Facebook (91,6%), Instagram (38,8%), LinkedIn (15,7%).

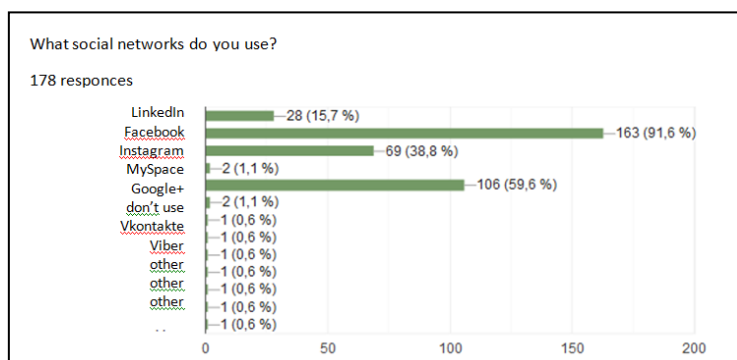


Fig.3. The diagram shows the diversity of the social networks used by respondents.

Section 6 is about the use of the cloud computing tools by educators for the professional activities. This is show in the diagram (Fig.4).

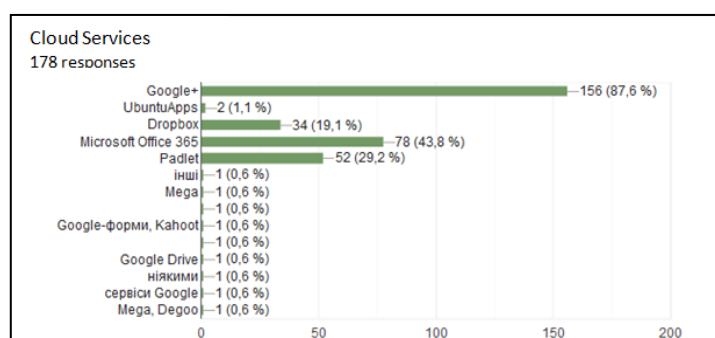


Fig.4. The diagram on the cloud computing tools used by teachers and school heads for teaching subjects and organization of the education process.

Most of the respondents choose Google+ (87,6%) as a most convenient for the professional purposes. It has to be noted that this service is not available now, but in the past years teachers has been frequently used Google+ and reflected this in the answers. They also noted Microsoft Office 365 (43,8%), Padlet (29,2%), and Drop Box (19,1%) as a most used nowadays.

The section 7 shows the picture on what ICT software do educators use for the management and administration of the educational process as well as for the implementation of teaching process in their institutions. The most popular is the Moodle tools (30,3%) and Shchodennyk platform (48,3%). Among other tools which are less used (approximately 0,6% each) are: Google Classroom, Netop School, Classrom, Atutor, SMS Global, OpenEdx, Joomla, Vitrual'na Uchytels'ka, ISUO KURS, Google services, Open EDX, NetSupport, DayPaD. There is also 0,6% respondents who do not use any of the instruments.

The section 8 is about the self assessment of the information and communication competence. The fig.5 shows the diagram on the self assessment of the educators.

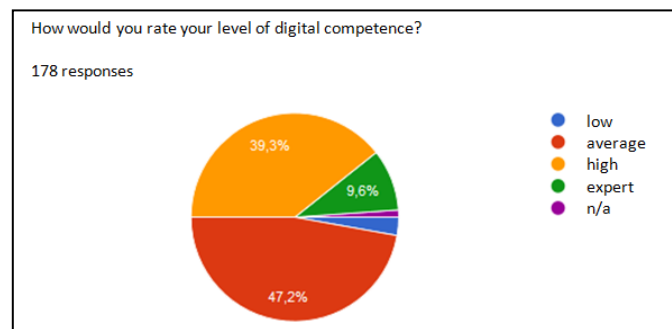


Fig.4. The self assessment on the digital competence shown by respondents-educators.

This part of the study was aimed at the revealing of the feeling of the respondents about their skills and competencies in using ICT. It was proposed express their vision regarding their level of the digital competence through 5-grid scale (Fig.4). The self assessment of the information and communication/digital competence was distributed in such positions:

- 47,2% (red) - intermediate level;
- 39,3% (yellow) - high level;
- 9,6% (green) - expert level;
- 2,8 (blue) – low level;
- 1,1% (violet) – do not know.

The self-assessment of the professional activity of the pedagogues is considered as a basis of a teacher's professional competence is his/her practical readiness for self-organization, which consists of the ability to plan his/her activity, to properly allocate his/her time and to find the best ways of its organization, the ability of self-control, self-analysis and self-assessment of its results (Mammon O.V.) [10].

The section 9 is about the attitude of the respondents toward ICT using in the teaching process and professional development. Their attitude was assessed on the 10-grig scale (from 1- low level, up to 10 – high level positive attitude). 57,5% showed the high attitude (10); 16,1% support 9th grid of the attitude; other respondents distributed their attitude between 8th and 5th scale.

In the final section of the survey it was asked the respondents to express their suggestions for raising awareness of the use of ICT in their professional activity. The suggestions were the followings:

- get acquainted with new technologies on the permanent basis - 78,1% (139 respondents);
- try to choose a special course on ICT in the post-graduate institution – 59% (105 respondents);
- find time to the experience exchange with colleagues – 56,2% (100 respondents);
- combine my institution's efforts to create a digital environment – 32,6% (58 respondents);
- I have a personal professional interest in advanced training – 50,6% (90 respondents);
- find time for raising awareness in the sphere of ICT and digital teaching – 43,7% (76 respondents).

5 Conclusions and Recommendations

The conducted study allowed to reveal not only the self-assessment of the educators' digital competence, but also to define how the ICT are used in their professional activities, which of these ICT are more popular and less popular among teachers. Also we also learned about respondents' Internet access and the popularity of the use of social networks for the professional purposes. It was extremely important to reveal the respondents' digital competency self-assessment.

Therefore, based on the above mentioned in the article, we can draw the following conclusion: from the teacher's ability to self-analysis and self-assessment of activity depends on the growth of his pedagogical skills and competencies, their attitude to use new technologies and ability to learn all over the life.

The *scientific novelty* of the research is in the identifying the gaps in the use of ICT in teachers' professional activities and for the professional development: lack of information and knowledge on the existing tools and instruments, lack of the digital skills and competence, lack of the information about didactical approaches to the ICT use. This is crucial for teachers now because of current situation with remote learning in time of COVID-19.

The *essence of the research method* is in the data gathering about the attitude of teachers towards the ICT tools use and their level of awareness, the revealing of their public opinion in this sphere.

The *practical relevance* of the study is to provide recommendations for the system of in-service teacher training on how to use digital tools for teaching and professional development:

In particular, it is suggested to use: web-based resources for teaching the educational disciplines, including distance courses; systematic collection of information and

using of the educational tools necessary for mastering of academic disciplines (programs) accessible through the Internet (ex. local area network); a web browser and other software available to the user. The important is the existence of the web-based distance learning environment in the educational institutions and in the in-service teacher training institutes (a systematically organized set of web-based learning disciplines (programs) as well as web-based resource management software equipped with the distance learning tools, and distance learning management. It is extremely important to raise the awareness of school administrators about the organization and management of the distance learning.

During the practical classes, it is suggested for teachers to use free cloud storages (repositories to access working materials and official documents of the school in shared folders, ex., School in the Cloud, Shchodennyk and other). The use of Microsoft Office 365 and Drop Box is also preferable.

Educators should also pay attention to international digital education platforms that they can apply to their own practical work. Among them: plus.etwinning.net (<https://www.etwinning.net/en/pub/etwinning-plus.htm>), a platform for educators that unites Ukrainian teachers today; schoolsonline.britishcouncil.org (<https://www.britishcouncil.org/school-resources>), a British Council website for teachers containing teaching materials and resources for teachers; EPals.com (<https://busyteacher.org/15965-e-pals-com-busy-teacher-detailed-review.html>), EPals Global Community is a place where learners connect; knowmyworld.org (<https://knowmyworld.org>) offers webinars for teachers to share experiences; <https://www.penpalschools.com>; Echo; www.leraar24.nl; <http://www.surfspace.nl>, the platforms for exchanging practical experiences among educators in Europe.

Massive open online courses (MOOCs) are also offered to teachers. Those teachers who are able to participate in the English speaking environment can attend a number of teachers' MOOC free online courses on science, languages and other subjects.

To assess the level of the teacher's digital competence, it is suggested to use online self-assessment tools, including: online barometer of collaboration skills using cloud services, MENTEP TET-SAT tool (<http://mentep.eun.org>). It is important to take into account the Digital Competence Framework for Educators (DigCompEdu) and the Digital Competence Framework for Citizens (DigComp), which contain specific descriptors of 8 skill levels and descriptions of digital competence components.

The following methods of assessing digital competence are proposed: ongoing assessment; team working with the educational managers and methodologists; self-assessment; team working with colleagues for evaluation of achievements; development of the individual work plans; providing observations of the lessons by the skilled colleagues; conducting regular problem analysis, surveys; creating portfolio; conducting activity research. The assessment of the digital skills of teachers can be done in the form of exams, testing, observation of the teaching process etc.

The results of the survey conducted in 2019 can be useful for the domestic curricula developers and those practitioners who plan and use digital tools in the education process. *The data shown in the results of the survey prove that the attitude of teachers towards the use of digital tools for their professional development differs according to the Internet access, their competencies and motivation.* These three is-

sues should be taken into account by the in-service teacher training system in Ukraine.

Further research can be conducted on the comparative studies of European and domestic experience of the use of digital tools for distance education. The use of the digital tools for the assessment of teachers' and students' digital competence needs particular attention. Modern educational science requires a broader deployment of comparative studies and empirical research in the field of teachers' professional development regarding the use of ICT. This can help practitioners to construct the digital teaching environment for their subject areas and enrich their educational techniques and professional development.

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Developing Training Materials for the On-Line Course "Project Method in Teaching Higher Mathematics"

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Abstract. The article reviews the process of developing training content of the on-line course on the project method for Mathematics teachers teaching at higher technical universities. The study presents the first stage in developing training materials and a model for the structure of the on-line course «Project Method in Teaching Higher Mathematics», which is in open access on the «Higher School Mathematics Teacher» educational platform. The original version of the course was designed on the basis of the findings of a survey among the Mathematics professors. It helped to find out the level of their awareness about using the project method in training engineering students. It also gave the authors of this paper good reason to recommend the on-line course for the professional development of Mathematics teachers. After uploading to on the platform the original version of the course, we managed to organize a discussion of the proposed content, structure and modes for submitting the course materials on the forum. The article discusses the process of modifying the course components, improving training material during the forum discussion. The analysis of the feedbacks from the course users on the forum, confirmed that the variety of submitted forms of course materials and the proposed topics satisfied the preferences of the course users with regard to the perception and awareness of the educational information.

Keywords: Project-based Learning, Training Content, On-line Course, Higher Mathematics Engineering Education.

1 Introduction

In the context of rapid technological development, there are many changes in the engineering education objectives, in which the emphasis is now placed on students' constant self-improvement, their ability to formulate a problem, find ways to solve it. While studying the training of technical speciality professionals, Lima et al. [1], van Hattum-Janssen [2], Fernandes et al. [3], Mills and Treagust [4] substantiated the fact that traditional teaching methods in higher engineering institutions (HEI) cannot meet the requirements of modern education. While expressing dissatisfaction with existing mathematical training programs for engineering professionals, more and more educationalists are becoming supportive of using active teaching methods. Thus, Weenk and van der Blij [5], Manrique et al. [6], Stojcevsky et al. [7] stress that the use of active teaching methods stimulates students' thinking and understanding the need to acquire knowledge for solving different issues of their future professional activities. Facing the necessity for students to become aware of the need for gaining knowledge, Felder and Brent [8] studied the ways to motivate students to become active participants of the educational process. Freeman et al. [9], while conducting the experimental study of the effectiveness of active teaching methods based on the principles of Sciences, Technologies, Engineering and Mathematics (STEM), proposed to use project methods in teaching.

There is a considerable amount of research on the topic of project-based learning. While studying the role of a teacher in the project-based training of future engineers, Van Hattum-Jansen [2] and Fernandes et al. [3] described project approaches in engineering education. Lima et al. [1] studied the issue of effective management of interdisciplinary projects in engineering education. Powell and Weenk [10] defined project-led engineering education, reviewing in detail the tasks and principles of this training technology. Zamyatina et al. [11] analyzed the advantages of project methods, shared the experience of implementing project-based learning in the educational process of an engineering university.

Despite the considerable amount of research on project-based training technologies, we still come across a number of controversial issues. The expediency of project-based teaching of junior students who study technical specialties still remains an open issue. Realizing that project-based learning of Mathematics contributes to establishing cross-curricular relations and solving problems of professional nature, Higher Mathematics teachers in Ukraine express their readiness to introduce this method into the educational process even for 1- and 2-year students. Expressing their desire to master the methodology of using project technologies, the majority of the interviewed teachers opted for training in the format of an on-line course. The analysis of the findings [12, 13, 14, 15] shows the effectiveness of using on-line courses for the professional development of teachers. This type of on-line courses is becoming more and more popular and has a number of advantages, such as following: the opportunity to work the training material through when it is convenient for teachers, in a comfortable environment, at their own pace and independently of others. In addition, the format of

the on-line course allows to diversify the modes of presenting the learning material, taking into account the user's individual needs. The forum users also have an opportunity to establish productive communication with their colleagues in order to resolve professional issues.

To find out approaches to developing on-line courses we turned to the papers by Perikos et al. [16], Wrigley et al. [17], M.Puzziferro and K.Shelton [18]. Comparing massive open on-line courses, which describe the development of training materials, and analyzing them, the scientists pointed to the importance of ongoing communication with future users of the courses when developing content. Scholars have described the use of different types of questionnaires to help the course developers verify that the training content lives up to students' expectations. Researchers designed these questionnaires to clarify the issue «What is the market of an on-line course and what they want». In addition, for those who are setting up to develop an on-line course, researchers advised following the experts' recommendations.

Having studied the general recommendations of Leicester Learning Institute [19] regarding the forms of presenting, structuring, and selecting content for on-line courses, we started developing training content for the «Project Method in Teaching Higher Mathematics» on-line course [20]. The original version of the course was uploaded to the «Higher School Mathematics Teacher» learning platform [21]. While designing this course, we took into account the concept of creating this platform, described in detail by Vlasenko et al. [22].

Therefore, the purpose of this study is to present the findings of the process of developing training content for the on-line course «Project Method in Teaching Higher Mathematics» [20], namely, the selection of content, effective forms of teaching material, with reference to a preliminary survey of Ukrainian teachers and further discussions on the forum.

2 Method

While analyzing the possibilities of implementing project-based technologies in teaching Higher Mathematics in Ukrainian technical higher educational institutions, we surveyed the lecturers who teach Mathematical disciplines in higher school. To estimate Mathematics teachers' awareness of the project methodology of teaching, we worked out a questionnaire using an open on-line service and placed it on the «Higher School Mathematics Teacher» platform [21].

About 100 teachers of different ages, with different teaching experience (from 5 to 30 years) from Eastern, Central and Southern Ukraine participated in the questionnaire and the discussion of the problem. The majority of the respondents were from the following educational institutions: Donbas State Engineering Academy, Donbas National Academy of Civil Engineering and Architecture, the Institute of Chemical Technologies of the East Ukrainian Volodymyr Dahl National University, Cherkassy State Technological University and Pryazovskyi State Technical University. We also interviewed about 30 graduate students of Kryvy Rih Pedagogical University and Berdyansk State Pedagogical University, who plan to work as Higher Mathematics

teachers in technical HEI. The questionnaire consisted of 10 questions. The questions were designed with the purpose to find out:

- the degree of Higher Mathematics teachers' awareness of the project method of teaching;
- the degree of students' readiness for project activities;
- the teachers' willingness to work with on-line courses;
- the reasons that do not allow for effective use of the project method in teaching Higher Mathematics;
- the place and role of projects in teaching Higher Mathematics;
- most popular types of projects;
- optimal academic load, which should be given to project activities.

The analysis of the respondents' opinions helped us formulate the purpose of the course. It is to transform the existing theoretical experience on project technologies into easy-to-use educational content, to provide methodological recommendations on how to use the project method with consideration for the specifics of the subject of Higher Mathematics. To define the concept and the structure of the «Project Methods in Higher Mathematics» on-line course we used the Inductive Content Analysis Method. When choosing resources for analysis in Table 1, we focused on those that offer project-based Mathematics learning. There are such on-line resources as Australian National University [23], Professional Development Service for Teachers (PDST) [24], Teach Thought we grow teachers [25], Study.com [26], The Curriculum Project [27], Computing Technology for Math Excellence [28], MIT OpenCourseWare [29].

Table 1. Analysis of the Structure of the On-line Resources Offering Project-Based Mathematics Learning

On-line re-sources	Theoretical components	Practical components	Project Bank	Tasks for users	Questions to course tutors	Restrictions on access to the course material
Australian National University	Research papers on the project method, theoretical information for each topic	Practical solutions on how to use projects in teaching Maths	Projects topics for getting Degree Builder	Research practical tasks	Through the forum	Access to courses is limited in time
PDST	Research papers on the project method	Videos on real-life classroom situations and live discussions between the lecturer	Projects topics for teaching Maths at primary schools	Accomplishing tasks during Workshops	Through the forum	Participation in Workshops is limited in time

		and the students working on the project				
Teach Thought	Research papers on the project method	Practical solutions on how to use projects in teaching Maths	Project topics for teaching Maths at primary and high schools	Accomplishing tasks during Workshops	Through the forum	Flexible
Study.com	Research papers on the project method, theoretical information for each topic	Videos on real-life classroom situations and live discussions between the lecturer and the students working on the project	Projects topics for teaching Maths at primary and high schools	Quizzes and practice tests	Through the forum	Flexible
The Curriculum Project	Research papers on the project method, theoretical information for each topic	Practical solutions on how to use projects in teaching Maths	Projects topics for teaching Maths at high schools	Training workshops	Through the forum	Participation in Workshops is limited in time
Computing Technology for Math Excellence	Research papers on the project method, theoretical information for each topic	Presentations on the use of projects	Topics for multimedia projects and projects on the Web-development	Test preparation	Through the forum	Flexible
MIT OpenCourseWare	Research papers on the project method, theoretical information for each topic	Presentations on the use of projects, videos on real-life classroom situations and live discussions between the lecturer	Sample Maths project topics	Execution of projects in a team	Through the forum	Flexible

		and the students working on the project				
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Taking into an account the structure of the reviewed resources, and analyzing volunteers' responses, we shall now consider the concept of the course in detail.

The course material is divided into the following blocks.

Block 1. *Theoretical component of the course.* This module includes research papers on the project method and the required theoretical information for each lesson of the course.

Block 2. *Practical component of the course.* This module includes:

- practical solutions on how to use projects in teaching Higher Mathematics (projects that have already been tested in educational practice);
- video-lessons lasting up to 10 min. In these video tutorials, the course instructors briefly explain the theoretical issues of the course. Also, the course tutors are planning to create videos on real-life classroom situations and live discussions between the lecturer and the students working on the project.

Given that the course is intended for Mathematics teachers and students who master the profession, a significant amount of material is presented in the form of diagrams and tables that clearly demonstrate the logical connections between the basic concepts.

Block 3. *Project Bank.* This module contains project topics that should be used in teaching Higher Mathematics. Project topics are systematized by specialties and types of projects. The course moderators have the opportunity to constantly update this module with new topics.

Block 4. *Tasks for Teachers.* This module includes practical tasks to each topic of the course. The tasks placed here have a different format because working with the course involves self-assessment and peer assessment. Here are some examples:

- to work out an indicative plan for the implementation of the project on the specified topic (a sample plan is provided);
- to distribute the given project topics among students with different academic achievement levels, to provide justification for this;
- to evaluate the situation the students are in while working on the project, to outline ways of pedagogical influence to overcome it.

Block 5. *Questions to the Founders,* which you can ask to the course tutors at the forum and express wishes on the course improvement.

The objectives and basic structural elements of the course are presented in Figure 1.

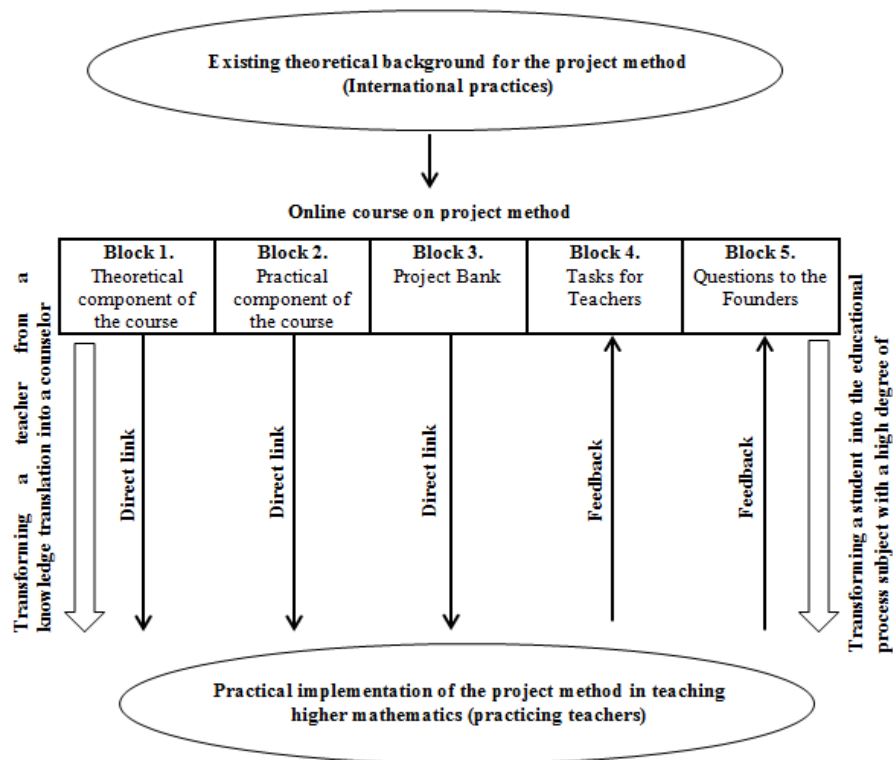


Fig. 1. The structure of the «Project Method in Teaching Higher Mathematics» on-line course

3 Results

The analysis of the results of surveying of Mathematical disciplines teachers at Ukrainian higher education institutions gave grounds to state that:

- only 45% of the respondents are familiar with the basics of the project method;
- 85% of the respondents are not sufficiently aware of the essential characteristics of the project method, and as a result, it is often confused with other methods (often with the problem method);
- 78% of those surveyed do not understand the essence of implementing the project method in teaching Mathematics;
- only 27% of the respondents believe they are ready to effectively control students' project activities;
- 74% of those surveyed do not understand, how to choose objective criteria to assess project activities and how to recognize the results of the project implementation within the overall rating of the discipline.

These results confirmed our opinion about the relevance of developing the on-line course, which will cover the issue of using project technologies in teaching Higher Mathematics.

Among the important reasons why the project method is not used as often as it is desired: 80% of the teachers bring out the lack of time to develop, prepare and manage a project; 70% of the teachers mention the shortage of information on possibilities of implementing the project method in teaching Higher Mathematics; 60 % point the lack of willingness to use the project method in teaching. As a result, we have developed several on-line course lessons aimed at enhancing the teachers' motivation to implement project technologies in learning Higher Mathematics and a bank of project tasks with ready-made project examples.

36,4% of the teachers equated educational projects with profession-oriented tasks, 26,4% of the teachers equated educational projects with application-specific tasks, 35,5 % of those surveyed identify educational projects with intergraded tasks (see Fig 2). That is why, a significant part of the theoretical and practical content of the course is focused on comparing and explaining the essence of the above mentioned concepts.

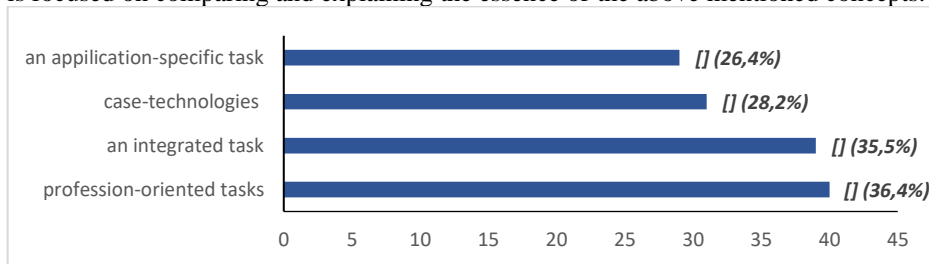


Fig. 2. Distribution of the teachers' opinions on comparing educational projects with other types of tasks

55,5% of the respondents think that profession-oriented learning the best corresponds to the principles of the competency-based approach to learning. 46,4% of the teachers give the second place to the project method. 32,7% of the teachers believe, that in the third place there should be problem-based learning. For 25,5% of the teachers, context-based learning comes fourth (see Fig. 3).

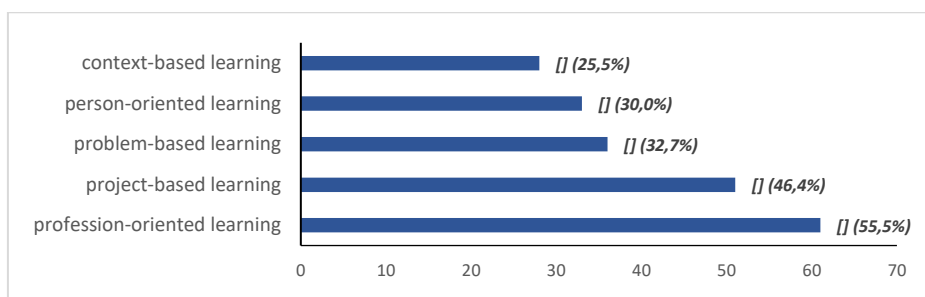


Fig. 3. Distribution of the teachers' opinions on choosing the priority type of learning

35,5% of the teachers consider, that students will demand constant assistance while working on the project. The other 20,9 % assume that the most difficult part of working on a project for their students will be the development of a detailed project im-

plementation plan. 5,4 % of the teachers think that the most difficult issue for their students will be the understanding of the essence of the project tasks. 9,1% of the teachers believe that their students will require the most help at the stage of analyzing the results of the project activity and formulating conclusions (see Fig. 4).

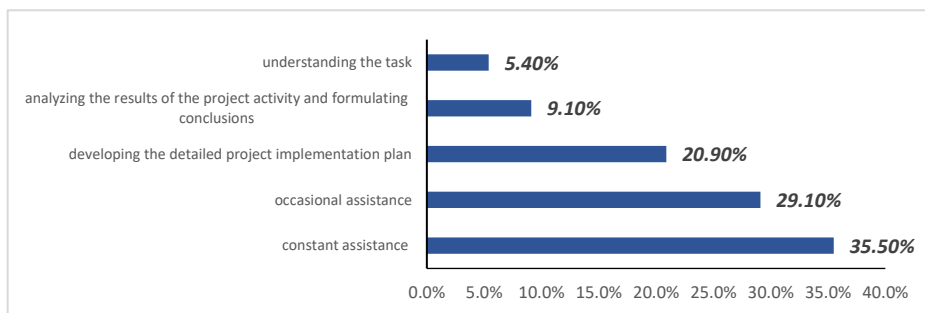


Fig. 4. Distribution of the teachers' opinions on the need to support students while working on projects

The data in this diagram served as a basis for developing tasks for teachers, the implementation of which will improve the quality of managing project activity of students at appropriate stages.

The analysis of the respondents' answers also helped us decide on the topics for the on-line course. The teachers were proposed to discuss these topics at the forum. 45% of the teachers pointed out that they were familiar with the basic ideas of the project method. Those teachers were invited to participate in the discussion of the original version of the on-line course. Thus, 44 teachers took part in the discussion of the course topics. The results of this discussion are presented in Table 2. The table shows the number of those teachers who gave the positive answer to the corresponding question.

We made all changes to the program and course materials to meet the needs of its users. The teachers' opinions made it possible to consider the issue of students' assessment according to the project activity as a separate topic. Moreover, we added the topic «Mini-Projects as an Effective Way to Prepare Students for the Implementation of a Project on Higher Mathematics». We took into account the teachers' wish to consider the application of the Inquiry method in teaching. Also through the forum, we obtained confirmation of the teachers' wish to work with the course.

Thus, the course is presented in Ukrainian and consists of 12 classes. We took into account the fact that the teachers may have no possibility to do more than two lessons per week. So, the course is designed to last for one and a half months. The users can start training at any time convenient for them and work at their own pace. Having estimated the maximum time required for each lesson to be 2.5 hours, we determined that the total course duration is 30 hours.

Table 2. Results of the Discussion of the Course Topics

No	Preliminary course topics	Accepted unchanged	Should be modified	Requires more than one lesson
1.	History of the project method	42	2	0
2.	Definition of the project. Significant and insignificant features of the concept	44	0	0
3.	Project method and problem method. Similarities and differences.	21	23	3
4.	Case-technologies and STEM-technologies	36	8	0
5.	Context method and project method	34	10	0
6.	Types of projects	28	16	2
7.	Good practices of using the project method in teaching Higher Mathematics	42	2	4
8.	Syllabus on Higher Mathematics with account for the use of the project method (place of projects, time input, topics, etc.)	35	9	5
9.	Practical classes on Higher Mathematics with the use of project technologies	23	21	8
10.	Project Reporting (execution Options)	10	34	32

The relevance of the on-line course content was discussed and approved during the International Conference on Sustainable Futures: Environmental, Technological, Social and Economic Matters (ICSF 2020) (Vlasenko et al. [30]).

4 Discussion

Kostrova's research [31] in the field of engineering education underlined significant isolation of Higher Mathematics from general engineering and speciality subjects. We share the opinion of Pais et al. [32] that students are often not aware of the specific purpose of studying Higher Mathematics, although, even in their junior years, they are oriented towards their future profession. This is the reason why the scientists point at the significant decrease in students' interest in this discipline. Following the scientists, we also criticize the fact that most teachers of Mathematical subjects prefer traditional teaching methods while students are just passive listeners during almost all of their classroom time.

We share the ideas of Kolmos et al. [33] on the feasibility of using project technologies in engineering education. It is obvious that project-based learning is an important tool for students' self-development and self-management and facilitates their rapid personal growth. However, unlike most researchers, we consider it not only quite possible but also advisable to use the project method for teaching junior students at technical universities. Analyzing the Mathematics teachers' willingness to use the

project method in teaching, we decided to keep disseminating among Ukrainian teachers the idea of using the project method.

The experience of Harris and Martin [34], Pelkola et al. [35] helped us elaborate an opinion that using such an on-line course is an effective means of remote professional development of Mathematics teachers in case they use the project method. We took into account the guidelines on developing an on-line course given by Hi [36], Burgess et al. [37], Donnelly and Agius [38], Volkova et al. [39], Lockwood [40] who recommend to use different forms of presenting material: images, diagrams, animations, and so on. The scholars also insist on the relevance of conducting a preliminary survey of the course users in order to prepare and improve training materials.

We also took into consideration the opinion of Im and Chee [41], who insisted on the importance of using forums for quality research. Using the teachers' comments on the course materials posted at the platform forum, we were able to adjust the learning content and confirm its readiness to be introduced into the process of further training of Mathematical disciplines teachers at Ukrainian HEIs.

5 Conclusions

The review of the pedagogical literature gives reasons to state that the project method of teaching is experiencing a surge of popularity again. The use of project technologies in teaching Higher Mathematics is appropriate and didactically grounded by the experts in the field of engineering education. The analysis of the results of the survey, done among higher school Mathematics teachers confirmed the lack of their awareness about using the project method in teaching. At the same time, it showed their willingness to improve this situation with the help of the designed on-line course «Project Method in Teaching Higher Mathematics' on-line course» [20]. The preliminary approbation of the course gives grounds to claim that it can be successfully used as a means for professional development of higher school Mathematics teachers.

Placement of the course on the «Higher School Mathematics Teachers» platform allowed for free access to the course materials. The development of the course structure and topics were based on the analysis of the results of surveying Mathematics teachers and the existing educational resources providing on-line education. The teachers' willingness to personally participate in the modification of the topics and materials of the course contributed to their engagement in the discussion of the course development at the platform forum. That, in turn, made it possible to expand the amount of the submitted educational material, forms of presenting educational content in order to the course users' preferences regarding the perception and understanding of educational information. The analysis of the answers of the first users of the course gave grounds to claim that the content and topics offered satisfied their preferences.

Among the directions for further research, we outline the introduction of the developed on-line course for the purpose of improving the readiness of Mathematical disciplines teachers at higher schools to use the project method in the practice of training engineering specialty students.

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Engineering in Educational Institutions: Standards for Arduino Robots as an Opportunity to Occupy an Important Niche in Educational Robotics in the Context of Manufacturing 4.0

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Abstract. The article reflects the views on the development of the engineering area of education and, in particular, its robotic vector. We do not claim to be “*the ultimate truth*”, but the issue is urgent and it requires extensive coverage and discussion in the community in the context of the development of the educational field of Technology. The question of the methodology and technics on the basis of which robotics courses will be taught, as well as design and construction, is considered. Within the CBLE “Clever” experimental study, an excellent construct and a huge number of author’s methodological guidelines were approved, tested and worked out. Educational designers are used, including during the engineering solutions prototyping. We focus not only on Lego products. There is a “technological boom” in the development of free software and hardware platforms, in particular, this is due to the appearance of the Arduino board in its various forms. It really gave rise to a “*breakthrough*” wave in technical creative work. Robbo-ScratchDuino, mgBot, and hundreds of others offer individual components and serious kits for future designers and engineers. Laser milling machines and other CNC machines, robots, quadcopters, 3D printers and other devices based on microcontrollers flooded the world. The development of electronic prototypes has been simplified many times at schools and a great amount of startups are being created. The educational effect is possible only with the systematic nature of such decisions and at least a certain uniformity in requirements. The main problems of implementing free software and hardware solutions (free educational robotics) into educational courses are offered.

Keywords: Variable models, Free educational robotics, Arduino, Roboplatform, mBlock, Computer-oriented methodological systems of research teaching, Engineering education, Research teaching, Scientific and technical creativity, Smart home, LED, Controller, Photoresistor, Piezoemitter, RIP.

1 Introduction. Analysis and Possible Solutions with the use of Free Educational Robotics for Educational Institutions

Modern trends in the development of education, the emerging demand from the state and society are pushing schools to introduce the basics of engineering into their educational practice.

Modern trends in the development of education, the emerging demand from the state and society are pushing schools to introduce the basics of engineering into their educational practice. It is necessary to create full-fledged conditions for the formation of technical thinking of students in a certain school. This is a whole complex of conditions of a technical, financial, organizational and methodological nature, which allows students to be oriented toward science, research, and engineering education. And many problems of this complex are solved by a team of like-minded people in collaboration with parents, associates and with the support of the educational administration [1].

On the basis of the analysis of international experience, ways of solving problems concerning the design of the learning environment and the construction of variable models of subjects in the natural sciences and mathematical cycle with the use of functional modules of the computer-based learning system (CBLE) are proposed. CBLE “Clever: School of Natural and Mathematical Sciences” is based on scientific concepts, including the results of previous researches of advanced scientists: theoretical aspects of the concept of L. Vygotsky [2], [3] V. Davydov [4], D. Elkonin [5], P. Galperin [6], A. Leontiev [7], S. Rubinstein [8], S. Papert [9], J. Piaget [10] which are the foundation of new state educational standards and are focused on the practical educational and cognitive students’ activity, the formation of the younger generation as the basis of a new society of knowledge [11], [12], [13]; scientific and technical creativity and handicraft [14], [15], [16]; international initiatives STEM, MINT, NBIC, TechShop [17], [18] and Others (European Society for Engineering Education, International Federation of Engineering Education Societies, etc.) [19]; Principles of Convergent Natural Sciences and Engineering Education [20]; principles of blended and adaptive learning [22], [23].

Different educational courses “Design and Research”, “Robotics”, etc. and hobby groups “Young Ecologist”, “Young Technician”, “Young Forester”, “Digital Laboratories” are organized on the basis of educational institutions. They deal with research and project activities, the study of mathematics, physics, biology, chemistry, ecology, geography, as well as information technology and scientific and technical creativity [24]. Teachers of primary school, biology, chemistry, mathematics, physics and IT aspire to lay the foundations of engineering thinking into their students. And here we face one of the problems of implementing engineering into school – the lack of an engineer profile in the educational process.

An important role in the work is given to the usage of modern educational, laboratory and demonstration equipment. In primary school children already have the opportunity to visually study the properties and phenomena of the world around them, they form the entire perception of nature, learn to set up experiments in a playful way and develop skills in setting and achieving goals. A mobile set (15 netbooks) was transferred to primary classes, which allowed students to master working with a pro-

ject-oriented environment. Students of grades 5-6 study Scratch in extracurricular activities [25].

The development of digital laboratories in high school is carried out in the form of small educational researches, during which students assemble experimental facilities from ready-made sensors and measuring instruments. Students learn to formulate conclusions on the basis of the experiment justifying them with the data obtained.

The most difficult type of activity for teachers and students is the implementation of individual and group projects, including the research part and elements of engineering developments. Such project aims at creation a real product and requires coordination of the work of different participants. Motivation to learning and choice of engineering professions is achieved through the usage of *research and simulation practices*, as well as various types of significant activities. Interactivity is provided by the usage of exhibits, laboratory and demonstration equipment, interactive software, electronic educational content, as well as active forms of organization of educational process, research and design activities of students [24].

Within the CBLE “Clever: School of Natural and Mathematical Sciences” scientific research events on ecological education, planting saplings of trees grown in the school farm are held [1]. The educational work conducted by children as part of their work with forestry is one of the most powerful tools for motivating technical creativity and developing technological competencies. In outdoor events, through active participation in the game, each participant gets the opportunity to try on roles that correspond to different professions in the engineering field: engineering, energy, forestry. As part of a scientific project, students of our schools practise in the areas of: agronomy and agricultural technology, veterinary medicine and zootechnics, forestry [25].

In engineering education of the students, the basic educational areas are: in-depth study of physics, mathematics, biology, chemistry, ecology and other disciplines of the natural science cycle. In order to attract high school students to the basics of engineering education, teachers of several schools (among them, former engineers and electronics engineers) launched a face-to-face distance learning project called “Educational Robotics”.

The programme includes computer repair training and helps teachers in the vocational guidance of students in the field of information and telecommunication technologies. The base of the project is a distance course on a Google website with relevant material and diverse tasks. Students are supervised by their teachers locally. To increase motivation personal and team championships were organized. The work has been going on since March and will last until mid-May.

At school, we are preparing to restart the project “Measuring work on the ground”, which combines humanitarian and natural mathematical disciplines, the main goal is the formation of meta-subject competencies of students that contribute to the development of universal educational actions for understanding a holistic picture of the world. The usage of modern software and technical equipment allows to most fully and effectively carry out a whole range of diverse work on searching the information, its analysis, systematization, evaluation, generalization and visualization.

The project “Measuring work on the ground” is carried out jointly by teachers of geometry, computer science, physics, history and geography, after an extensive material related to this topic has been accumulated in the geometry course. Practical tasks promote the formation of a correct understanding of the nature of mathematics. As

you learn the material, the methods for solving problems change; the same problem can be solved in many ways. The following geometry questions are used: equality and similarity of triangles, relations in a right-angled triangle, properties of right-angled triangles, etc. A new unit has been added for the development of engineering thinking: meteorological observations, creation of a soil-climate passport, measurement of the physicochemical parameters of water in a pond and a stream.

The place of the project in the educational process is extremely important in terms of the formation of basic and profound knowledge, skills, and abilities. Interdisciplinary links enhance the overall educational effect of this project.

While working on various projects, we always initially start with existing patterns and templates. I remember my teacher in the radio engineering club. In the second year of study he brought us an old broken receiver, without some details. He asked to restore the model. We did - it seemed to be not bad, everything worked. By the way, an almost new and the same receiver was in the teacher's closet. And when we compared the devices, it turned out - we made the radio in our own way, using other ideas. In his activity, the student goes through the phase of apprenticeship, where instructions, technological maps are simply necessary. Although it's always more interesting to invent, fantasize, sculpt from a scattered pile of parts a device which was conceived only by yourself.

In most cases, the proposed robotics kits cannot be used without reworks "*on the knee*" (done in a slapdash manner) (even soldering is used) and the purchase of components (batteries and chargers). A child or an unprepared teacher is not able to use such a kit, and a prepared teacher will not do this when it is necessary to provide with such kits the whole class.

A common marketing policy for proprietary and free solutions is that the manufacturer offers expansion kits or the ability to purchase the individual components. In this case, the functionality and completeness of the basic version of the kit, as a rule, is cut so much that it becomes almost impossible to use, and the proposed extensions are disproportionately expensive. There is an alternative option - "*all inclusive*", but there is practically no way to increase functionality. And the completeness of the proposed kit is still in doubt.

Some used technical solutions are not suitable for tough operating conditions in educational institutions and lead to a very rapid failure of the equipment. Accordingly, maintainability leaves much to be desired

A robot is a complex "*intelligent*" device, which is capable to perform the function assigned to it and to perform work (!) in changing conditions. The main thing is that during the educational process there is a "*game*" in robots, but you should play as seriously as possible. The robot should be able to connect different executive bodies corresponding to the training "*production*" task. In some training situations, you can go without them, but the set of such tasks is limited and should be well researched methodologically and provided with appropriate hardware solutions. It is important that the educational robot should be able to change, transform, demonstrate complex diverse behaviour in changing conditions, in other words, to fulfill the functions of a personal entertaining robot, maintain and develop children's interest every lesson, which is especially important in the conditions of a non-profile educational institution.

The “*smartness*” of educational robots is very limited, and to maintain the children’s interest, games with remote control should be used more widely, where some of the actions are performed by the robot itself in automatic mode. Such an approach assigns primary importance to the question of a convenient, easily organized and reliable remote control for each robot within the training class. As a rule, the tools used for this in modern robotic sets are far from perfection.

2 Educational (non) Free Robotics. Requirements for Developers of Robotic Kits who Would like to Occupy an Educational Niche in Schools

Based on the analysis of the research results [1], we can state that each developer is trying to create his own configuration that is incompatible with competitors and even with their own products of older versions, while there are a very limited number of logical options. For example, for *Arduino Uno* there is the only motor control scheme from among the common and used ones that minimally limits the possibility of further upgrade (*D5-D4, D6-D7*). It is recommended to accept it as a standard [26] for using in educational institutions. Software developers enter artificial restrictions that prevent the work with unfamiliar or hand-made robotic kits. An alternative is free educational robotics, focused on creating a truly high-quality compatible product which integrates the advantages of different solutions. Positive examples (*MakeBlock, iArduino, MGBot*) are used in the “Clever: School of Natural and Mathematical Sciences” pilot research.

Requirements for developers of robotic kits who would like to occupy an educational niche in schools. Of course, for the development companies it is very financially tempting [1]

A logical motor control scheme, non-use of ports with unique capabilities for performing research tasks [27], which can be assigned to “*ordinary*” ports provides, as a consequence, variability in increasing the capabilities, each product can be easily modified for specific tasks. For example, port *D3* may need to be used to control an additional motor, or to interrupt processing that occurs when the state of the port changes. It is recommended to accept a twin-engine scheme using the *D5-D4, D6-D7* as a single standard.

Focus on the use of ready-made electronic modules with easy convenient connection. A standard common interface for connecting the necessary modules. For example, RJ-25 with the absence of the possibility to connect incorrectly. Freedom while choosing the manufacturing of such modules independently by any student, up to the organization of a company for their production, uploading the corresponding schemes and instructions. The ability to use a cheap common element base for peripheral devices with easy connection without soldering, or with minimal soldering, for example, line and obstacle sensors, Bluetooth modules HC-05, gyroscope MPU-6050. Adjustment without soldering, available to the child. A wide range of ready-made modules. Saving the possibility for experienced users to refine the ready element base by soldering, including the refinement of the robotic controller to solve specific problems. The product line from elementary school to infinity [1], in the same style of the used

components (manipulator machines, printers, milling machines, various kinds of robots, quadcopters, etc).

Low entry threshold in various aspects. First of all, like *Scratch4Arduino*, *mBlock*, *Snap*, and for creating *ArduBlock* self-contained programmes, it is possible to use visual programming languages for working in an interactive mode. At the moment *mBlock* is the only sphere of elaboration that allows you to use both of these modes in the practice of working with children. Therefore, the hardware configuration of the robotic kit provides the easy use in this software sphere. In addition, in the *mBlock* sphere, it is possible to develop specific extensions for alternative hardware components and provide support for their own *robotic controllers*.

The kit includes a complete set of everything you need, including a screwdriver for assembly. You must first resolve the issue with the batteries and a charger. Reliable, durable, as well as beautiful construct, convenient for assembly by children themselves, arouses their interest. Wide design base for further expansion of opportunities. The possibility to transform the structure with different uses (speed, high possibility and stability, balance, etc.) for optimization. Relatively compact sizes, which are important during storage.

The set contains a convenient box for long-term storage of the exploited set. Boxes should be easy to stack and carry for practice. The possibility to install ready attachments, or assembled one from the model kit. The possibility to connect a sufficient number of external engines (2-4 or more, including servos). The possibility to use a simple and complex system of motion control (based on encoder information). The possibility to change the location and orientation of various sensors in a wide range. Ergonomics of use (power switch, button control, LED indication, etc.).

Protection of sensors and electronic schemes, including the presence of a hull. Availability of easy-to-use fault-tolerant solutions for wireless control of a robotic platform from a computer, tablet or additional Arduino-device in the classroom. A wireless connection for training robots should be organized so that its setting does not take time of the lesson.

The presence of a description of the way of connecting modules (sensors, actuators). Support for two options at the same time is desirable: a three-pin *SVG* connection using *Dupont* wires and a method that provides protection against incorrect connection. For example, *RJ-25* or *RJ-9*. A set that allows you to complete a full course of study in several versions, even in the basic configuration. The presence of easy justified redundancy of the kit without overloading it with unnecessary parts, an optimal set of electronic modules. *The composition of the starting configuration includes a gyroscope and a rotary head on a servomotor with an ultrasonic or infrared range finder*. These components significantly expand the capabilities of the mobile roboplatform and can stimulate the interest of children due to its greater personification and variability, as well as an interconnected set of educational game tasks.

For example, a piezo emitter was included in the "Smart House" project. The possibilities of using the programme in *mBlock* when working with a piezo emitter were demonstrated. We used a special high-level order of control to create a security siren in the Fig.1. We complicated a little bit the programme by adding a start button control in the Fig.2, Fig.3.

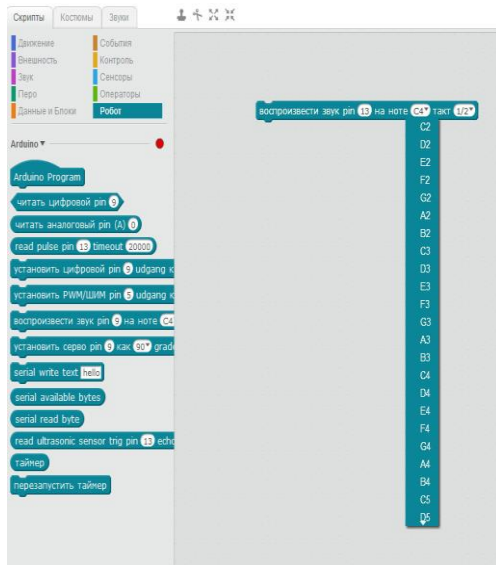


Fig. 1. Programme in mBlock (Siren alarms).

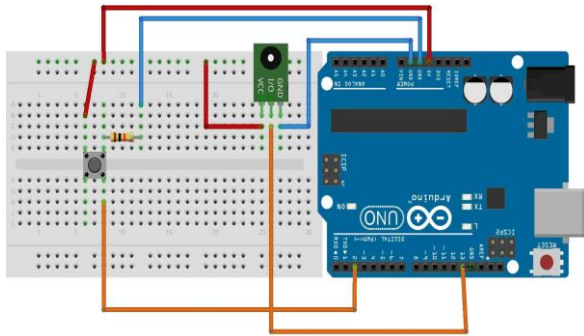


Fig. 2. Assembly scheme.

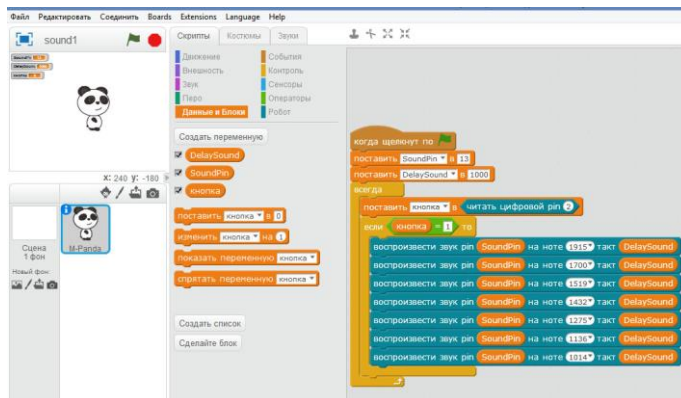


Fig. 3. Programme in mBlock (USB connection).

An example of a programme in creating a musical instrument in which the sound will be changed when the hand blocks the light stream falling on the photoresistor. The connection scheme of the photoresistor to the board in the Fig.4 is given below.



Fig. 4. Photoresistor Module Connections to Arduino.

The button was removed from the assembly scheme, but if it remained from the previous project, it can be used at the discretion, for example, to change the frequency ranges in the Fig.5. In the project, the photoresistor connection pin is changed to A0 in the Fig.5.

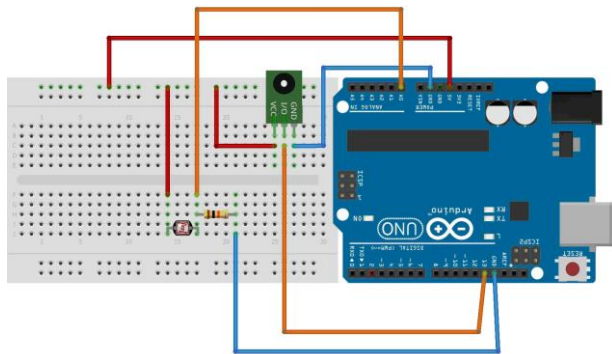


Fig. 5. Assembly scheme.

We introduce the variables: przPin - indicate the connection pin of the photoresistor; przReading - is a variable for storing data from a photoresistor; soundPin - indicate the connection pin of the piezo emitter; soundFreq - variable for storing sound frequency; sound_freq_max - set the maximum emitting frequency; prz_max - set the maximum value of the photoresistor. The programme is given below in the Fig. 6.

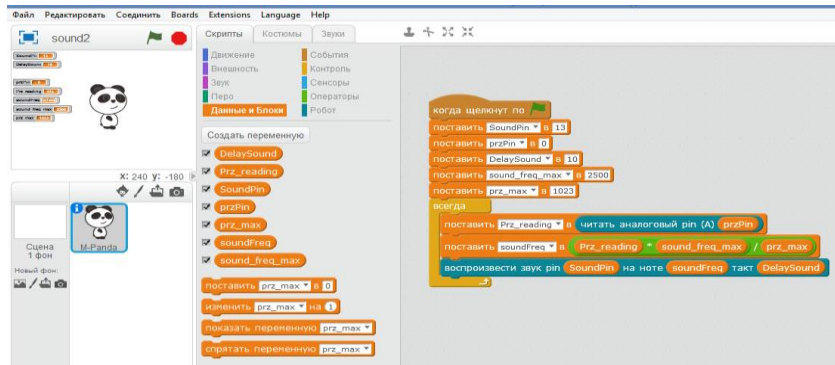


Fig. 6. Example programs in mBlock.

A version of the programme with a decrease of the number of input variables in the Fig. 7.

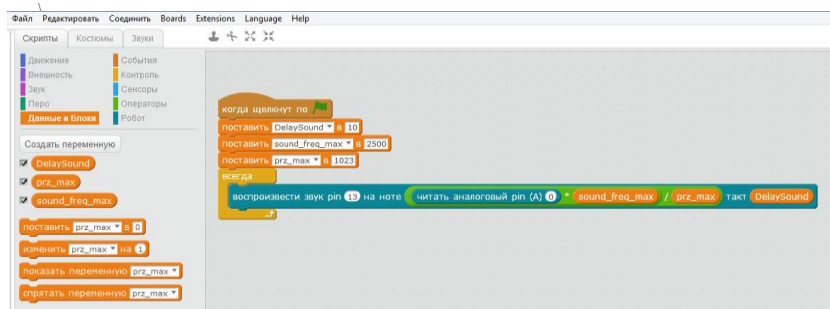


Fig. 7. Example programs in mBlock.

Within the “Clever: School of Natural and Mathematical Sciences” research, using Arduino-based training kits, many research projects have been developed (from “Smart House” to “Design Bureau”) taking into account different options for using sound, a piezo emitter, several browsers, and LED control (*ScratchDuino + mBlock or Snap laboratories*) [1], [26].

3 Engineering Projects at School

Table for Sand Animation. In primary school, for a long time, students were engaged in plasticine animation. We came to the idea to do sand animation in order to expand the creative range, to develop the fine motor skills. With the participation of 6-7 graders, a table for sand animation was made. (i.e. a frame and a glass stand). I had to tinker a bit with the backlight and the video system. Along the perimeter there are fluorescent lamps. Web cameras are put into two positions - above the table and under the glass. Fixing video on MTS was performed by using Intel Education Media Camera by Intellisense (A programme for taking pictures and video, initial processing of photos and videos, as well as creating presentation reports based on the footage).

Potter's wheel. After the excursion to the local history museum and the ceramic factory, students were eager to create and sculpt from clay. It was necessary to make a potter's wheel. Information on the Internet and the necessary spare parts (based on a DC motor with a frequency regulator, a small pottery wheel) were searched. It was also important to choose the right clay for vessels not to crack.

A Device for Determining Specific heat by Plastic Deformation. In our educational process, we often adhere to certain patterns. As practice has proven their effectiveness, low time costs, good efficiency. In physics lessons, the specific heat of substance is usually measured using a calorimeter, while the specific heat of the glass material of the calorimeter and the liquid poured into it are considered to be known. Everything has been worked out over the years. However, it is important for school-children to be aware of other methods that make it possible to measure specific heat without using information about the specific heat of other substances. One of these methods is based on the phenomenon of heating of solids during their plastic deformation. In general, we can say that the project was carried out using hand-made equipment, as well as a digital laboratory and a temperature sensor [1].

We often use competition elements in our work. Most guys, of course, prefer team work. There are individuals. You can motivate them to work in a team. To do this, one should create situations in which such a child has to leave his comfort zone. A distinctive feature of our projects is that the solution is often unknown, and students must independently gather information and choose the best solution [27]. The children are encouraged to cooperate not just because of their next home assignment, but because of a real engineering solution that should work. There are situations when you have to work with one child. Therefore, more often we have teams of different ages, when there are children with different skill levels and abilities. We form teams due to the preferences and skills necessary for the project.

In our digital days, when everyone has a mobile entertainment center in his pocket, a means of communication and access to virtual resources of the whole world, the question arises – what is it for to assemble a radio, an electronic toy or to program a sensor? It seems to many of us that these children are trying to do this for themselves, for their pleasure [24].

We bring broken devices, equipment to school and disassemble them with children, trying to repair. For example, once a schoolboy's home iron was modernized. It turns out that in old devices there is no thermal fuse, so the idea came to add an element from the discarded one. And now the fire safety of the home device is ensured. When children work on real projects referring to adulthood, attracting all the power of modern digital technologies, the products created by them as a result are more functional and demanded than our childhood crafts.

The work with children continues during the holidays. Summer school "Clever: School of Natural and Mathematical Sciences" is an already established element of educational activity in our school. The main area of work is a school educational experimental site and a school nursery of seedlings. As part of the work in this area, I'd like to attract 1 student to the design of automation and control tools. Among students in grades 5–7, we use the Tetra educational kit (a ready-made training course for children to learn the basics of programming and modern electronics, Scratch support). With several students of grade 10, they plan to master the Raspberry Pi [1].

Attention is focused on a deep knowledge of programming, computer graphics, robotics, the Internet of things, learning the theory of solving research problems [24]. Indeed, in order to become an engineer, they go through a significant study of various disciplines, where the leading subjects are those of natural mathematical cycle. The formation occurs over the years among a team of specialists, in the process of working on projects of any degree of complexity. Therefore, it is obvious that today a teacher who guides extra classes and clubs of an engineering and technical cycle should have a large amount of knowledge and skills of interdisciplinary area [29]. His competencies as a specialist should allow him to be flexible enough, able to work in the new changing conditions.

4 Discussion

A modern school needs high-quality educational robotic kits, and they exist, but in a very diverse version. Minimum requirements are necessary for the standards of constructing a device scheme, so that students independently and under the teacher's guidance, can work with any educational sets. The base should provide standard tasks. The current discrepancy in the configuration of hardware platforms makes it impossible to create universal methodological materials. Judging from this, the market situation is changing. Prospects for the engineering vector of education development have appeared. Those producers who do not aim at leaders, but continue to work in isolation (each for oneself), risk making sure that nobody needs their products.

However, there is always a lack of technological resources. There are sets of equipment that teachers purchased at their own expense. An appropriate technical base is needed, and this is not only educational robotics. We need interaction of educational institutions and industrial companies in cities, agricultural enterprises in the countryside to perform vocational guidance of children in engineering areas.

When choosing a software and hardware platform for developing new training courses in mobile robotics based on Arduino in primary and secondary schools, we focus on *MakeBlock* kits and *mBlock* software, as the ones that best meet modern requirements for quality, capabilities and applicability in activities with children, we also deal with compatible options (variable models).

We are not fans of *Makeblock* and their *mBlock* software product. If it were a Ukrainian, and not a Chinese company, we would be proud of such thoughtfulness of our products. But while the reality is like this - of all that we could use at school, the *Makeblock* product line came closest to what we would prefer to see at school (*although they are not ideal, sensors must be protected for school use and a servo pack should be included in basic set for ease of purchase, etc.*).

As a part of the study, educational institutions use "free" platforms. All *MakeBlock* products are well documented with the possibility for children to revise on their own. The *mBlock* software product based on Scratch 2.0 has versions for *Windows*, *Mac* and *Linux*, supports most Arduino boards (and not just the company's own controllers), various connection types, and also has a mechanism for writing extensions by any users [1], [24], which allows to adapt for control a huge number of electronic components in this area. Currently, *mBlock* is the only Scratch-like environment that allows everyone including children to work conveniently with microcon-

trollers in both interactive and offline mode. This is also worth thinking about for our software developers. Convenient *RJ* connectors are used to connect the electronic components, which makes the assembly as convenient as in Lego, *but at the same time these are ordinary connectors that are easy to crimp on your own.*

Variability and Functionality of Product Line. The product line includes: kits with simple *mBot* robots, kits with a powerful robot *Ranger* (three options for standard assembly), a set of *Ultimate* components (10 standard robots + space for creativity), sets of artist robots (a machine for round objects, a hand, a drawing robot on wheels), kits for assembling plotters (including laser ones) and two types of 3D printers, modular octocopters, extended kits with sensors. The basis is milled aluminum.

The students emphasized the advantages of the controller in a transparent protective box, which has 12 *RGB* LEDs, a pair of light sensors, a buzzer, sound and temperature sensors, a gyroscope, a couple of buttons, a powerful engine with encoders. What is more they admitted the comfort of using modules to create their own sensors. It is important that the control environment is similar to the usual *Scratch*, but it gives the opportunity to control all the electronics. In addition, students are willingly designing octopapers, planes and various cars using *Airblock*.

In the Evolvevector construction sets (set of advanced Robot +), it is necessary to admit the presence of a high-quality training manual and thoughtful interesting tasks. The set has its original aspects. For example, the wires are already soldered to the motors. But this construction set cannot be recommended for use within the framework of a non-profile comprehensive school. The orientation towards using the Arduino IDE (instead of visual programming tools like Snap4Arduino, Scratch4Arduino and mBlock) should be taken into account, which drastically reduces applicability and pushes back the entry threshold. A set of tasks for ordinary (not selected) children and teachers should also be different.

For example, as part of the “Clever” scientific project, students play robofootball with pleasure, or solve design research problems with a plot background. Here we talk about creating universal teaching materials suitable for conducting classes using any compatible Arduino robot platform, and the content of these classes is not limited by struggle with the discrepancy described in the methodology and the actually used hardware configuration.

In today’s market, with regard to robotics, the kits and standards for minimum sets are offered: Using the *Makeblock* kit5 you can assemble three modifications: a crawler all-terrain vehicle, a high-speed wheeled balancing robot. It is recommended to add a servomotor pack to each one, making it yourself. Using the *Makeblock* kit we assemble four modifications of drawing robots, including manipulators. This is the easiest option, including a laser (engraver), etc. A kit for the independent manufacturing of *Makeblock* sensors. Using full compatibility with Arduino peripherals and a unified programming environment, we assemble 7 standard robot circuits described in the manuals and many of our project variations [30].

As part of the Clever study, we tried many different options, including during sessions with the use of electronics. Obviously, various modular solutions are optimal for school, for example, a kit with modular basis components with three-legged sensors, SVG, and joystick modules, modular buttons, relays, slide potentiometers, button assemblies, a joystick shield, a prototype shield optimized for connecting three-pin modules, a motor shield, a shield for three-pin sensors, etc.

The experimental results confirm that the use of such key solutions, supplemented by three-pin sensors in SVG modules, makes it easy to assemble circuits even in the primary school. Children willingly make their joystick to play Scratch, or control the robot from a distance, and then a similar assembly becomes a digital laboratory, or an element of a smart home [24]. For kits based on *Orion* and *mCore*, as well as other *Arduino* controllers, you can use the ready-made module and using soldering you can use the GY-521 based on the MPU-6050 chip instead. The *mBot Ranger* kit has a gyroscope, the *Auriga* controller includes it. Solutions based on *STM32* (including *Iskra JS*) are future of microcontrollers for using during the training process. As part of the study, a complex with a set of training tasks is used for a whole robotics training course.

Domestic developers need to pay attention to compatibility with *MakeBlock* products, and, accordingly, with the *mBlock* software environment. For example, we are talking about compatibility with products: based on *Arduino Uno - mCore*, *Orion*; based on *Arduino Mega 2560 - Auriga*, *MegaPi* [31].

Experimental and Research Activities in the Field of Education. Experimental and research activities in the field of education are carried out in order to ensure the modernization and development of the educational system, taking into account the main areas of socio-economic development of the country, the implementation of priority areas of state policy in the field of education. The experimental activity is aimed at the development, testing and implementation of new educational technologies, educational resources and is carried out in the form of experiments.

The research activity is focused on improving the scientific, pedagogical, educational, methodological, organizational, legal, financial, economic, manpower, material and technical support of the educational system and is carried out in the form of research projects and programmes implemented by organizations engaged in educational activities and other educational organizations, as well as their associations.

When implementing a research project, the respect for rights and legitimate interests of participants of educational relations must be ensured, education, the level and quality of which cannot be lower than the requirements established by the state educational standard and state requirements must be provided.

The study developed and tested an algorithm for selecting the optimal set of resources of the CBLE, which involves the use of quantitative criteria to determine the suitability of resources to the requirements of students and teachers. As a result, there is a need to develop variational models of science and mathematics education for students of natural-mathematical, technical profiles that differ in content, methods of teaching, etc. Students' testing that has been conducted for several years, monitoring the quality of knowledge, which was conducted in the process of teaching students, allows distinguishing several groups of students of different quality [1], [24], [25].

The first group consists of students (15.7% of the total number of students enrolled in profile classes), who scored less than 10 points in the test. Based on the results of practical exercises, the students of this group have difficulties in the process of mastering the curriculum, most of them eventually continue their education in ordinary classes and after graduating they enter higher education institutions. The second group consists of students (42.3%), who scored from 10 to 15 points in testing. Students of this group do not have well-formed computing skills, do not outstand with singularity of thinking, but in the process of systematic and gradual training they were

able to master the basic level curriculum and an additional specific component part. They are able to work well if their actions are algorithmic. In the future, about 70% of the graduates of this group enter technical higher education institutions. *The third group consists of students (24.6%),* who scored from 16 to 18 points in the testing process. These students have mastered the curriculum of secondary school fairly well, but for their further development it is necessary to develop their logical and creative thinking. Mostly all of them enter the chosen higher education institutions. *The fourth group consists of students (17.2%),* who scored more than 18% during testing. This group represents the most prepared part of students who have come to profile classes. They show considerable interest in science and mathematics. All of them 100% enter the chosen leading higher education institutions.

5 Conclusion

A set of variable functional modules of CBLE is selected taking into account the methodological theme and tasks of an educational institution, organizations, etc., its specialization, prospects of development, the need for integration with academic and business structures. During the development of the curricula of natural and scientific and technical course, it is important to choose the topic of research projects in a proper way and their realization would give the opportunity to unite the formulated goals and solve the objectives.

As part of the scientific research, the following activities are offered: Organization of development, testing and implementation of new elements of the content of mathematical education in science and technology (the Mathematical logic, theory of algorithms and games, the set theory, the theory of probability and mathematical statistics, etc.) in organizations engaged in educational activities.

Support of educational organizations including non-standard ones, implementing basic and additional educational programmes for the students who have shown outstanding abilities as well as students who have achieved success in educational activities, scientific (research) activities (gifted children, talented youth, young teachers and scientists (summer, winter, evening schools, etc.)

Creation of publicly accessible databases on educational programmes of the mathematical profile, approximate curricular of out-of-class activities, additional educational subjects of science and mathematical content in various educational subjects, courses for students. Improvement of the education system in Ukraine is possible providing the revealing of the relationships and a pedagogically balanced combination of the traditional system of learning with the individual components of CBLE through the creation of centers for intellectual development and scientific and technical creativity [1]. Using these recommendations will help solve the problem of technological competence development at different stages of the student's life and increase motivation to choose engineering professions, support personal and professional self-determination, project thinking of children, teenagers and young people in the modern mobile society.

Prospects of Further Research. It is necessary to refine the standardization of equipment using a free robotic platform. For example, the possibility of using ports

for motors, a minimum list of sensors on certain electronic modules, standardized *RJ* connectors with prescribed crimping logic should be provided. The work on creating textbooks and a textbook on Technology which is not based on Lego is going on. It is recommended to use devices based on Arduino in grades 8-11, including optional classes, clubs. While teaching educational robotics in grades 3-7 (8), it is necessary to introduce propaedeutic and extracurricular courses in grades 3-4, accordingly in 5-7 grades - during the study of Technology, including extracurricular work, too. In this case using a visualized environment such as *Scratch* makes it possible to focus not on the study of programming language but on the design and research activities. Rather complex technological projects with two-way communication systems, PID controllers, the use of a variety of sensors, actuators, etc. appear in these environments.

Currently there are only two visualized environments *mBlock* and *Snap4Arduino* for Arduino projects which allow not only to control the device interactively from Scratch-like environments but also to download programmes for offline work. At the same time the mechanism of creating a sketch for autonomy in *mBlock* is made convenient for a student and does not require unnecessary manipulations. That is why *mBlock* is now chosen as the basis. It is only necessary to refine the offline mode and provide convenient mechanisms for working with software and *Arduino* main boards.

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ICT for training and evaluation of the solar impact on aviation safety

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Abstract. The paper discusses information and communication technology use for studying reasons of aviation accidents because of the aviation operator errors as result of internal and external influence. The model and technique are proposed and include integrated ICT united previously developed (initial professional selection and day-to-day pre-shift check), open access cloud-based (NASA and ICAO) and real-time operative (air traffic controllers and pilots control) ICTs, which data are stored in one database. Proposed ICT has been checked to study effect of the solar wind parameters (speed and density) on appearance of aviation incidents and accidents during one year observation. Results of that study were compared with corresponding results of another period of solar activity, as well as with data obtained in laboratory conditions to study cognitive tests performance under effect of the solar wind.

Keywords: ICT, aviation safety, astrophysics, database.

1 Introduction

The number of air traffic accidents and incidents (ATA) remains significant despite the efforts of the aircraft engineers and air carriers. Most of the causes leading to the erroneous actions in the flight are complex [1]. The causes of around 30 % of all air traffic accidents still cannot be identified applying current criteria, according to the International Civil Aviation Organization (ICAO). Those causes of the air traffic accidents, which were previously identified as unknown, can actually lie in the astrophysical factors affecting the activity of aviation operators (pilots, air traffic controllers) [2]. It is known that the parameters of solar activity such as solar wind (SW) can have a significant effect on human physical and mental health, first of all, in space and aviation flights [3]. Previous ground-based researches under NASA support of the

Earth's surface have demonstrated that the negative impact of the solar wind parameters can occur at both high and even very low SW speed and density values [4].

Analyzing the reliability of the pilot in the aircraft control loop [5], the specialists stated that the most vulnerable link in emergent technologies is a lack of psychophysiological training, including soft skills (human factors) [6]. This is true in relation to flight crews as well as air traffic controllers [7]. To be prepared to the effective work, they need special training and re-training with the use of modern and appropriate technologies [8], accounted individual features of the trainees [9] and including adaptive tools [10].

Neurobehavioral performance in the structure of the «human factor» largely determines the success of professional flight operations and reliability of professionally important qualities in extreme situations [5]. Block psychophysiological qualities can be divided into specific, necessary for a pilot, quality (for example, cognitive abilities) and quality, providing resistance to the adverse effects of negative environmental factors (including greater influence of solar radiation, compared with Earth's surface) [11], compensated by the digital transformation of learning environment [12]. In general, it is useful to combine information regards a human psychological, psychophysiological and skills' features to assess and to predict the aviation personnel's reliability and safety, as well as information concerned work environment particularly solar wind components influencing a human performance.

Purpose. To develop the model and technique to study solar wind impact on aviation safety.

2 Methodology

The model developed to solve the task is based on the methodology for studying emergent industries operators' performance [13], and includes information about an aviation operator's psychophysiological abilities collected at stages of his/her professional selection and day-to-day pre-shift check, as well as extended by data from cloud sources the Aviation Safety Network (ASN) containing descriptions of the air traffic accidents that occurred due to human factors (i.e. category of air traffic accident, date, time, aircraft type, and location) [14], solar wind parameters at the time of each air traffic accident (speed V and density ρ), according to the National Oceanic and Atmospheric Administration (NOAA) [15].

The model of data collection and use for study a solar wind impact on aviation safety (air traffic controllers and pilots reliability) demonstrates the systemic nature of influencing factors (Fig.1).



Fig. 1. The structure of innovation performance indicators in ICTs

Stages of the Study Process:

1. Data acquisition and database creation based upon related information sources
2. Creation of histograms and analysis of the findings
3. Discussion and interpretation of the results

The technique to study the solar wind impact on aviation accidents and incidents includes:

Data collection

- Data related to the particular aviation operator (air traffic controller and/or pilot) after initial professional selection stored in the database (DB).
- Data related to the same person after training/re-training stored in the DB.
- Data related to the same person stored by the system of the day-to-day pre-shift check in the DB.
- Safety data from the Aviation Safety Network (ICAO).
- Solar wind data from the National Oceanic and Atmospheric Administration (NASA).

Data analysis

- Histograms construction for the solar wind's density and speed.
- Histograms construction for the ATA events related the same SW frequency intervals.

Observation period: June 1, 2018 to September 2, 2019 (solar cycle 24, minimal solar activity period).

Results and Discussion

The exposure to solar radiation during space and air flights can have a profound effect on humans' sensory nervous system. Moreover, other occupational groups of the aircraft industry (air traffic controllers) are also at risk of exposure to solar radiation. Thus, the solar wind has an ability to affect humans on the following three levels (Fig.2):

- On Earth's surface (air traffic controllers)
- In the upper layers of atmosphere (pilots)
- In the space (astronauts).

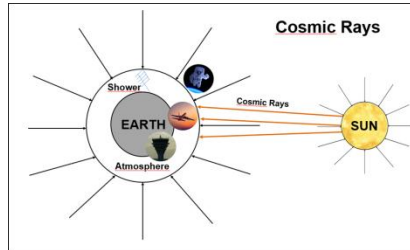


Fig. 2. Three levels of the SW impact on a human performance

However, the exact mechanism of such impact is not clearly understood yet. At the same time, it is known however that the Earth's magnetic shield deflects the primary particles of the solar wind (protons and electrons). This collision generates secondary particles in the atmosphere forming their cascades and an extensive atmospheric shower. As a result, an aviation operator's performance can be influenced by them depending on a human psychophysiological resilience and train level, including soft skills.

The main results are as follows:

- Total number of the documented air traffic accidents: 63.
- SW speed range by day: 294...612 km/s (57% of all ATAs: $V \leq 400$ km/s).
- SW density range: 0,3...17,1 proton/cm³ (60 % of all ATAs: $\rho \leq 3,1$ proton/cm³).

But the frequency distribution (using STATISTICS 6.0) of the ATA across the intervals of the revealed bounds of the SW density and speed is not uniform and has some "picks" in both parameters (Fig.3).

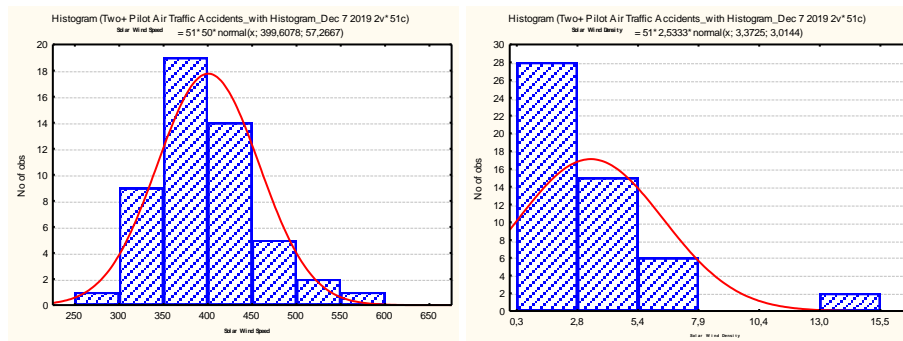


Fig. 3. SW density and speed across period of ATA studying

Distribution in accordance to intervals of the SW parameters in % of the whole numbers of events demonstrated very similar nature in relation to the SW speed (Fig. 4), but different distribution in relation to the SW density (Fig.5)

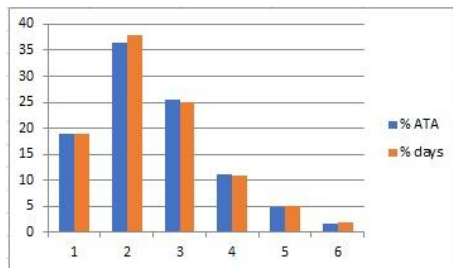


Fig. 4. % of the SW speed by intervals (see Fig.3) in comparison with ATA days

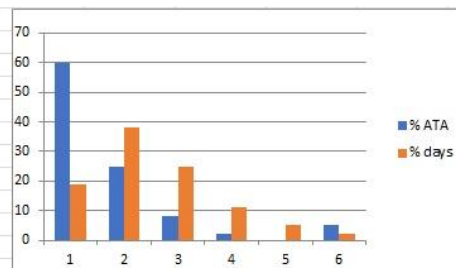


Fig. 5. % of the SW density by intervals in comparison with ATA days

These results correspond the results of the study a human-operator's cognitive changes under influence of the solar wind in laboratory conditions [4], but differ to some extent from the data of previous study [2] during observation period 1998-2009 (period of high solar activity of the 23rd solar cycle).

It has been confirmed the dependence of the probability of accidents on certain ranges of SW parameter values. However, in contrast to the known data about this dependence in the performance of cognitive activity in experimental conditions on Earth, it was revealed maximum impact on the speed of SW 500-600 km/s and density SW 7-11 proton/sm³.

The study concluded that the astrophysical factors should be accounted in the analysis of air traffic accidents to ensure flight safety.

The study confirmed that the solar corpuscular radiation can pose risks to human mental health, i.e. central nervous system. The frequency distribution of the air traffic accidents by SW speed and density is uneven with the peaks between intervals ranging as follows: 350...400 km/s for SW speed and 0...3 proton/cm³ for SW density.

The study has shown that further research is needed (i) to develop the aircraft accident classification by solar wind impact on certain types, phases, and geographical latitude of the flights, (ii) to assess the effects of SW proton energy on the activity of free neutrons and secondary protons in the atmosphere, and (iii) to examine the SW impact on the humans' individual and group behavior in outer space.

Those results have confirmed that "Ergonomics as a scientific and practical discipline is aimed at ensuring high efficiency of human activity, its safety and comfort. One of the ways to achieve such a triple task is to create an effective psychophysiological support for the ability to work in the process of both work and learning. Macroergonomic approach involves the systematic solution of issues of analysis of a certain type of activity, designing its optimal conditions, selecting and adapting a person to this activity, solving technical and organizational issues of providing effective and safe education and labor" [16]. Besides, such an investigation could be used to monitor human abilities over a lifespan: in education, training and work, as well as all kind of life [17].

3 Concluding Remarks and Future Work

The air traffic dispatchers and air carriers can use the SW data to assess the risk of air traffic accidents. The main difference in laboratory study and in real settings (aviation) can be explained by the professional training/re-training level, as well as by team and inter-person work in real aviation activity in contrast with the laboratory participated subjects, who performed cognitive tests and concentrated on the prompt cognitive activity not having professional training, though both type of mental activity studied used ICT.

Further study of the modern astrophysical data (including various periods of solar cycle) and their application for the air traffic controlling (especially in the high latitudes) will lead to better understanding of the correlation between SW and air traffic accidents and later, developing an exact action plan based on the biophysical observations of equipment and pilot behavior.

Further modernization and improvement of the dispatch equipment in the aircrafts will enable for additional information for computer prognosis.

Apart from that, it can be considered to reduce the duration of occupational exposure to the SW and provide medical and psychological recovery measures for the affected occupational groups to compensate for any potentially negative impact.

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Learning Style Identification System: Design and Data Analysis

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Abstract. The article analyzes different approaches to design adaptive educational systems on the basis of students' learning style identification. As a result of the investigation a system to identify the student's learning style with the data analyzing module has been designed and implemented. A data analyzing module is applied for the further adaptation of digital educational content and educational methods to students' learning style. The data background for the module to analyze learning style identification system is the universal e-learn environment users' database, the results of learning style identification due to VARK (visual, audial, read-write, kinesthetic) model or any open external information like psychotype, type of intelligence, etc. Data storage uses the concept of data warehousing to predict special methods for data model design taking into account the integrity of datasets from different sources, object orientation, consistency, data consolidation or multidimensional data architecture to simplify analytical queries. The data analyzing technologies being applied within the system are based on the information retrieval approach using SQL language; OLAP and Data Mining technologies. The results of the system implementation gave an opportunity to fix the correlation of learning styles with other personal characteristics like psychotype, gender, secondary education level, academic achievements, etc. The represented data of data analysis concerning IT major students give reason for the conclusion about the necessity to adapt digital content to multimodal and kinesthetic learning style, to apply learning methods and technologies on the basis of project tasks, group communication and collaboration.

Keywords: Learning Style, Design of the Learning Style Identification System, Technologies of Data Analysis.

1 Introduction

1.1 The Problem Statement

One of the digital educational environment key components is e-learning material including e-learning courses (ELC), e-tutorials, virtual labs, video lectures, multimedia resources, etc. The format to represent the same educational material may be different. For one and the same topic a set of textual materials, a multimedia guide, a training video, a webinar, etc. may be elaborated to differ in the way of perceiving the educational material in audio, visual, kinesthetic or verbal samples. The students often deal with educational content without taking into account their special features of educational content perception, leading to the results of no constant learning style adequacy. At the end it influences on the level of professional competence development and on studying achievements results. Student's learning style is developed due to many factors exemplifying psychotype, emotional state, physiological and other factors [1]. There are many scientific investigations devoting to the students' learning styles, automated systems of their identification or to adaptive e-learn systems but it is a lack in investigation of the item concerning information systems design to analyze not only students' learning style but the factors influencing on its formation or change.

The purpose of the article is to design and to investigate the ways of data analysis technologies application within the learning styles identification system.

Each student has own individual needs and special features being formed in high school [2]. The most of the systems to control educational content do not take into account these needs namely in adaptive courses providence. The majority of existing LMS systems do not support adaptability of the learning process, so it is necessary to focus on adaptive learning content management systems. In our research we will answer the following questions: How to determine learning style automatically and what technologies of analysis or for what purpose may be applied within the learning style identification system.

1.2 The Theoretical Background

Native and foreign researchers pay considerable attention to the study of students' educational styles. In [3] learning styles are defined as a set of cognitive, emotional, specific and physiological factors to serve as relatively stable indicators of how a student perceives, interacts with learning environment or responds to it. Most of investigations prove that learning style influences students' attitude to studying, satisfaction level and academic achievements within online educational environment [4]. While developing e-learn systems they take into consideration the need in taking into account a student's learning style to be proved by results publication of adequate investigations [5, 6, 7].

There are two the most spread methods to identify learning style: static one on the basis of learning style inventory and dynamic one on the basis of behavior mode while studying. Static method of identification is simply enough though it takes student's time for testing. Dynamic method of identification is based upon different methods application like neural networks, Bayesian networks or rule-based reasoning. In particular, many researchers have confirmed the efficiency of Bayesian network-based automatic

style identification. According to Feldman's review [8] Bayesian networks are one of the most widely used methods to identify students' learning style automatically [9, 10, 11, 12].

The models of learning styles are classified and are characterized by the way of educational content receiving and working out. The fundamental aspects of such models are cognitive styles and educational strategies. The most spread and known models of learning styles are VARK, Myers-Briggs, Kolb, Felder-Silverman and 4MAT.

Adaptive e-learn systems apply learning styles in order to propose valuable recommendations and regulations for students and scholars to optimize educational process [13]. Adaptive e-learn systems are considered to be one of the interesting directions within digitally based educational technologies [14]. The main goal of these systems is to propose the way to percept educational material on the basis of students' preferences, needs, educational experience, learning style, students' age, etc. [15].

[16] has reviewed above 50 investigations concerning integration of learning styles with the adaptive educational system. These investigations involve different aspects: from choice of e-learn environment learning styles theories, learning styles forecasting or learning styles automatic classification up to numerous systems to identify learning styles. Integration of learning styles into the adaptive educational systems is comparatively new trend within e-learn technologies.

The example of the above named systems realization is WELSA being described by [17]. In particular, there were functionality, designing tools, data analysis and WELSA system adaptation on the basis of dynamic content adaptation to the learning style investigated. The possibilities of one more adaptive Manhali educational management system are observed by [18]. The experimental observation of IT students' e-learn studying within the adaptive Manhali educational management system dealt with analysis and evaluation of students' behavior mode on e-learn platform as well as with the identification of their learning styles according to two learning styles theories: Kolb's theory and Felder's theory. The main goal was to study two important interconnections within the e-learn systems: interconnection of students' behavior mode with his academic achievements as well as interconnection of student's gender with his learning style. Paper by [19] reviews the design of adaptive educational system on the basis of several learning styles models exemplifying VAK (visual, audial, kinesthetic) and Felder. VAK learning styles include visual, auditory and kinesthetic samples while Felder learning styles include global and consistent ones. This system combines learning styles and extends benefits of regular e-learn studying - regardless of auditorium or platform. The research by [20] characterizes individual studying environment on the basis of adaptive taxonomy using learning styles by Felder and Silverman which combines with choice of adequate teaching strategy and adequate IT tools. The students have efficient opportunity to improve educational process with such method. Investigation by [21] observed the system to provide educational content being adequate to students' preferences according to Felder-Silverman's learning styles model. To optimize functionality of this system they applied the method of approximate ant colony optimization (ACO). The represented solution provides adaptive and personalized way of studying.

Many researchers proclaimed that learning style might vary in time and might depend upon task/ studying content [22, 23, 24, 25]. In particular, the goal of investigation by [26] was to identify students' learning style on the basis of identification using data

from mining web register concerning student's learning behavior mode. To classify styles, they used Felder-Silverman's model. This investigation proved that learning style is changeable during certain time. Thus, the system must adapt to changes for what the algorithm of artificial neural network for students' style forecasting is applied.

2 Implementation

Learning styles identification system on the basis of VARK model was elaborated within the National University of Life and Environmental Sciences of Ukraine. To analyze data OLAP and Data Mining technologies were proposed. From one side it gave opportunity to analyze learning styles in order to design adaptive content or to apply adequate studying methods and from another side – to analyze factors influencing learning style development and correction. Different students' databases and static method of learning style identification were applied for it.

2.1 The model of learning styles identification system architecture

The designed system is web-oriented, its functions predict authorization with the application of universal e-learn environment users' database, testing to identify learning style due to VARK model, noting additional data for each student to be in need for further analysis, data importing from system (psychotype, IQ), data exporting into analyzing module, formation of the recommended studying resources on the basis of learning style and their evaluating by students, formation of regulations to apply educational methods for scholars.

To identify learning style according to poll results concerning VARK methods they elaborated algorithms to identify predominant learning style basing upon testing students' behavior modes. There were following four learning styles to be identified:

- Visual type: information perception is more efficient if the represented information is underlined or colored; block-schemes are applied; images are demonstrated as well as video fragments, posters or slides; lecturers use gestures, bright facial expressions or figurative language; there are textbook diagrams to illustrate scientific information; curve graphs are applied; digital system to represent information is applied; individual time period for material perception is proposed.
- Audial type: information perception is more efficient while attending group lessons, discussion clubs; discussing scientific problems with other students; discussing scientific problems with scholars; explanation new ideas to other people; using audio recording; memorizing interesting examples, stories, jokes; pictures and other visual images; missing notes place to be filled up further after some details recognizing.
- Read/Write type: information perception is more efficient while it is represented as a list of concepts; in vocabularies, dictionaries in alphabetic order; in the form of glossary; in the form of definitions; in the form of handouts (theses); in textbooks; in the form of notes (reports); by scholars with correctly built speech using much information for every sentence, in the form of essay; in regulations, manuals for practical works.

- Kinesthetic type: information perception is more efficient while: all sensory organs are involved: visual, tactile, taste, auditory; studying takes place in labs; field trips and excursions are held while studying; action of any rule or principle (law) is demonstrated; scholar teaches material using real life examples; information is visual; there are approaches to allow perceiving knowledge on practice; the method of attempts and mistakes is applied; collecting visual material is practiced exemplifying samples of stones, plants, shells, etc.; exhibitions are organized, objects samples under observation are demonstrated as well as photo images of different scientific phenomena; the ways and tools to solve studying tasks are described, last year examination tasks are exemplified.

According to the proposed algorithm a multimodal style is distinguished in the case when no predominant style is identified.

To get other statistic data according to such factors as: gender; previous educational establishment (school, college); age; what is the child in family; psychotype (Myers-Briggs Type Indicator (MBTI) technique) [2], they performed data importing from other sources (Learning Management System “University”, potok.ua site). To realize IT providence they chose MySQL database where the data are stored in separate tables, due to what the speed and flexibility for work with data is achieved. The tables are connected each with other due to interconnection thanking to what the possibility to connect data from some tables while request executing is achieved. Physical data model is represented on fig. 1.

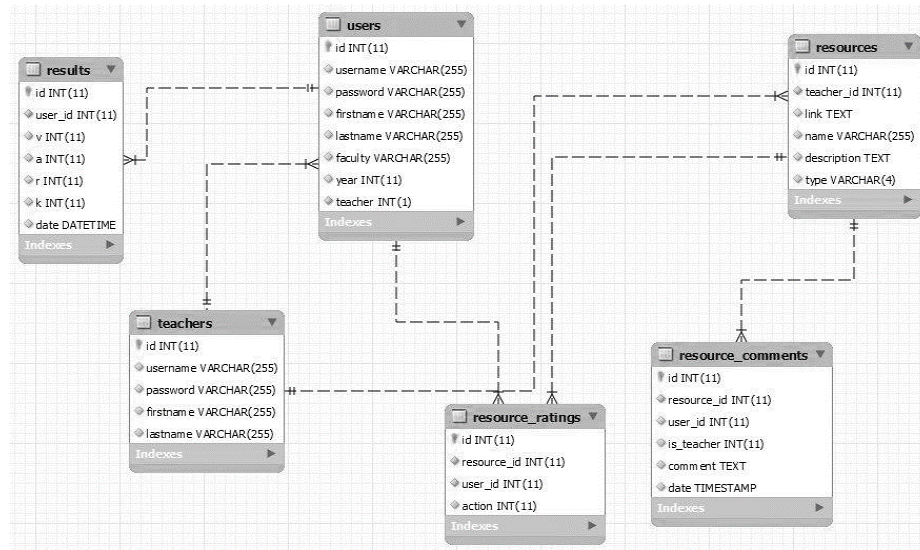


Fig. 1. The data model of learning styles identification system

General system architecture is represented on fig. 2. The scheme represents learning styles identification system – as one of modules within e-learning environment. Web

interface for static identification of learning style transfers data toward server for the further storage and analysis. Database of learning styles and other students' characteristics is stored within the system and is available for analyzing module. Interface for analyzing module gives opportunity to apply different methods of static analysis and intellectual analysis of data in order to determine the factors which mostly affect the learning style. Learning Portal includes CLMS, e-learn courses which obtain educational resources to take into account predominant students' learning styles using Adaptive Content Manager.

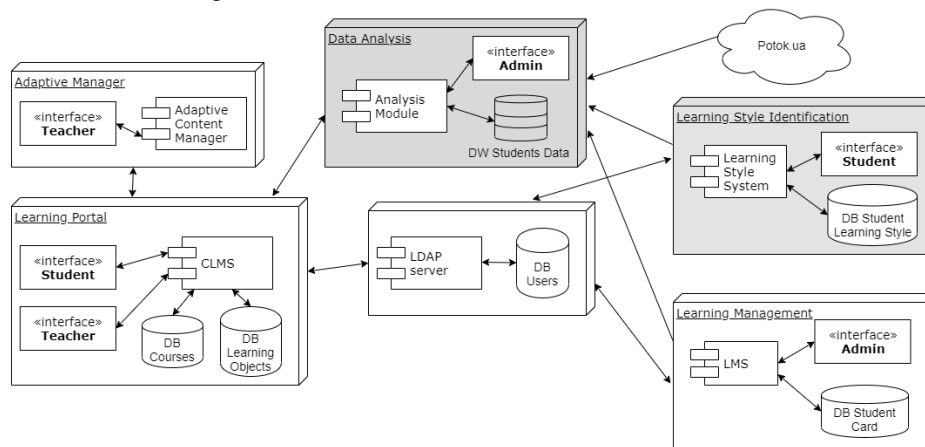


Fig. 2. Learning Styles Identification System and Analysis Module as part of e-learning environment

2.2 Data Analysis Module: data source, storage, analysis technologies

In order to design subsystem of analysis concerning learning styles identification system it is necessary to adopt decision about the data sources, data storage method and to choose technology for data analysis [27].

Data source. Data source involves operative systems of data proceeding exempling the universal educational environment users' database and the results of testing to determine learning style according to VARK model. Such data are received from the internal environment of system. In addition, the data source for subsystem analyzing may be any external information system (for example, student assessment data is from the LMS "University"). All data sources for analysis module are presented in fig. 2.

Data storage method. To store data being in need for analysis in order to identify learning style the *data warehouse* concept (DW) is used. The usage of DW concept predicts special methods to design data model involving such moments as integration of datasets from different sources; object orientation, data consistence and consolidation; multidimensional data architecture to provide simplification of analytical requests performance.

The essence of multidimensional data representation is that most of real business processes is described involving large amount of metrics, properties, attributes, etc. So,

for solving the task to identify learning style they need information about gender, previous educational establishment (school, college), age, what child in family or psychotype. If to select whole this information into two scaled table, it will appear to be complicated for visual analysis and comprehension. Moreover, it may be over norm if to take into consideration separate linkages like “psychotype-learning style”, “gender-learning style”, etc. All this complicates the extraction of useful information from such table. The mentioned problems arise due to only one common reason: two-scaled table stores multidimensional data

The background of multidimensional data representation is their division into two groups – *measurements and facts*. Measurements are categorical attributes, objects titles and properties being engaged into certain business process. Measurements qualitatively describe the observing business process; they are discrete by nature. Facts are the data to describe business process in a quantitative way, continuous by nature, that is why they may take infinite number of values.

Fig. 3 represents DW architecture, being designed for learning styles identification system.

The designed data warehouse consists of on facts table and eight measurements tables. The measurement “psychotype_dim” includes the list of psychotypes being observed within system; measurement “result_dim” deals with the list of the possible learning styles. The rest of measurements represents information which will allow specifying students’ data: gender, faculty, specialty, previous education, child in family. Measurement “year_dim” will allow to connect the received facts with year. It gives opportunity to determine student’s age (studying course at university).

The facts table “student_fact” includes information about concrete student. It obtains unique complicated key to combine primary keys for measurements tables. Besides these attributes facts table contains personal students’ data (identification number, surname, name and patronymic name, date of birth, year of entering University, average mark concerning the concrete period), attribute “value_domin” means the quantity of students’ questionnaire answers being adequate to one or another learning style after percentage transfer.

The represented multidimensional structure allows to track down the correlation of learning style with student’s psychotype, gender, age, etc. Such correlation may be represented either in series “learning style – psychotype”, “learning style– gender”, “learning style – age” or more complicated dependencies to take into account influencing of several attributes on learning style at once.

The data are delivered to DW from the operative sources through the OLE DB provider. OLE DB is a set of COM-interfaces allowing appendices to work with the data from different information sources and repositories. OLE DB separates data repository from the program which must have access to it through the set of abstractions including

data source (DataSource), session (Session), command (Command) and a set of rows (Rowset).

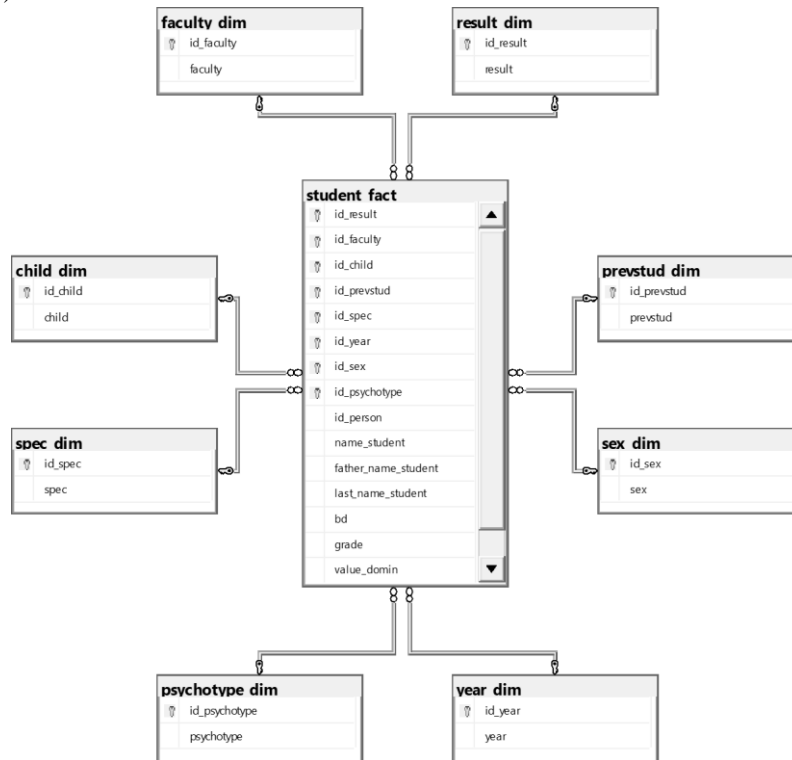


Fig. 3. Structure of data warehouse

The technologies to analyze data. The analyzing subsystem as a component of learning styles identification system is based upon information retrieval approach using SQL; operative data analysis (OLAP-technology); intellectual data analysis (Data Mining technology).

Information retrieval approach allows receiving data from DW tables by performance of requests, written in SQL. In such requests the data may be derived from the different DW tables according to different criteria and may be filtered under some conditions. For example, the request, represented on fig. 4 allows calculating the quantity of “Read-Write” style students who study at the Faculty of Information Technologies, questionnaire was held in 2018.

```
select count from student_fact inner join result_dim on student_fact.id_result=result_dim.id_result inner join faculty_dim on student_fact.id_faculty=faculty_dim.id_faculty inner join year_dim on student_fact.id_year=year_dim.id_year where result_dim.result='Read-Write' and faculty_dim.faculty='Факультет інформаційних технологій' and year_dim.year=2018
```

Fig. 4. The students' quantity request

The received results may be represented in the form of tables, charts or graphs etc. Operational data analysis (OLAP-technology) involves DW as hypercube allowing to perform special actions with it: *residual review* (formed as subset of multidimensional data array being adequate to the universal value of one or several measurements elements being out of this subset); *rotation* (the change of measurements location in report); *consolidation and detailing* (identify upper transfer from the detailed data representation to the generalized one and respectively vice versa). Such operations allow receiving information about value correlation from one or several measurements, rearranging rows and columns, retrieving generalized data and tracking what detailed data they are derived from.

OLAP-technology may be regarded as a set of services mentioning one of them to allow concluding reports on the basis of DW data, representing them in the form of tables, graphs, histograms. It simplifies data analysis and allows confirming or refuting certain hypothesis, for example, concerning the correlation of gender with learning style (fig. 5).

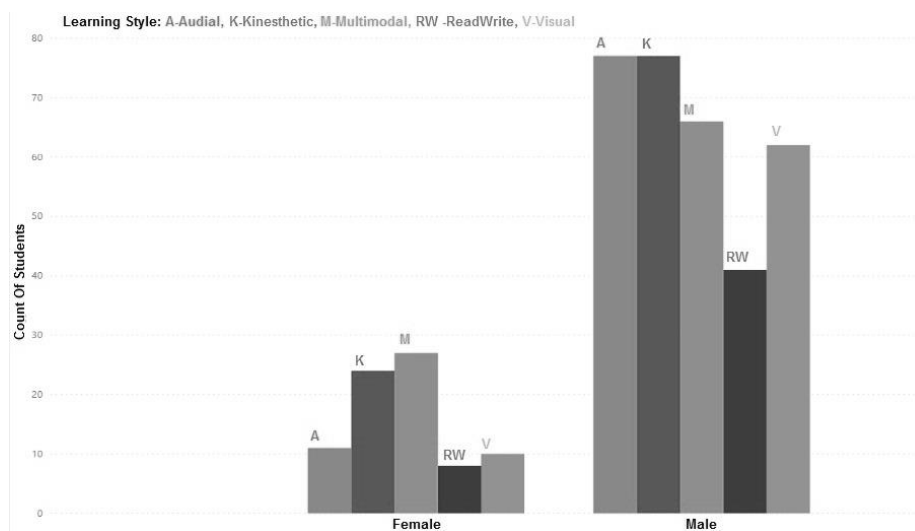


Fig. 5. Correlation of gender with learning style

Intellectual analysis, being based upon Data Mining technology, allow finding new regularizes between data, that is to obtain new hypothesis (new hypotheses) concerning the correlation between measurements and fact. To solve Data Mining tasks, they apply different methods and algorithms. To identify learning style, they propose to apply Apriori algorithm as an algorithm to search associative rules (the rules allowing finding patterns between related events).

Within the system under consideration it will allow assessing the degree of influence of different factors on learning style.

3 The Results of Experimental Work

The learning styles identification system obtains interface for students' and scholars' authorization, however it applies the authorization data within universal e-learn University environment; basic testing to identify learning style (fig. 6) and additional testing and questionnaires to get different facts being adequate for students and being in need for further analyzing.

The screenshot displays the VARK results page. The main heading is "РЕЗУЛЬТАТИ ОПИТУВАЛЬНИКА VARK" with the result "ВАШ ТИП НАВЧАННЯ: КІНЕСТЕТИЧНИЙ". Below this, a section titled "ВАШІ БАЛИ:" shows scores for four learning styles: Visual (0), Auditory (6), Verbal (1), and Kinesthetic (11). To the right, "ВАШІ РЕСУРСИ" lists recommended resources, categorized by type: "ТИП: ВІЗУАЛЬНИЙ" (e.g., "Розробка веб-сайтів з використанням Python і Django") and "ТИП: АУДІАЛЬНИЙ" (e.g., "16 корисних уроків по CSS3 для початківців").

ІМ'Я, ПРІЗВИЩЕ	ДАТА ОСТАННЬОЇ ЗДАЧІ	ТИП	
Вікторія Поліщук	09-06-2018	Кінстетичний	Всі результати
Олексій Савощенко	09-06-2018	Кінстетичний	Всі результати
Богдан Крамаренко	09-06-2018	Візуальний	Всі результати
Анастасія Бондар	09-06-2018	Кінстетичний	Всі результати
Student For Test	09-06-2018	Кінстетичний	Всі результати

Fig. 6. Resulting page

Statistical analysis according to the results of academic achievements for the second year students majoring in specialty "Computer Sciences" and their adequate learning styles allows paying attention on such fact that "Read /Write" style students obtain

more significant studying achievements (average mark – 82) comparatively to the students with other learning styles (fig. 7).

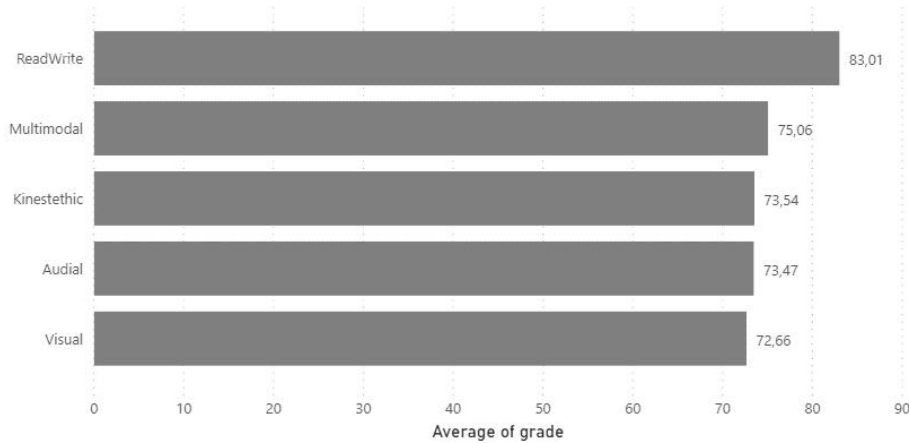


Fig. 7. Average mark of students with different learning styles

Having analyzed the educational content to be proposed to students within e-learn courses it was found out that e-learn courses mostly included educational resources with textual structural materials (48%), presentations – 36%, video resources – 12%. Such resources were the most favorable for the students with “Read /Write” learning style. At the same time, the percentage of the second year students majoring in specialty “Computer Sciences” (total of 78 people) with “Read /Write” learning style. was only 13 %. Thus, the educational content might be adapted to the students with kinesthetic and visual learning style. After it the second term of studying demonstrated the best academic achievements for students with multimodal learning style (82 marks), kinesthetic style (79 marks) and visual style (80 marks).

Basing upon the fact that the majority of that year students belonged to kinesthetic learning style (65%) the analyzing module gave opportunity to identify the most predominant psychotypes for that learning style (fig. 8).

One third of all students with this learning style belong to three out of twelve psychotypes obtaining the following psychological features:

Logic-sensory extrovert. He likes leadership and represents leader’s features, is rather responsible, has a developed sense of obligation, follows plan, does not accept deviations from the planned actions, is sincere, conscientious, holistic nature, does not like innovations

Sensory-logic extrovert. He has inexhaustible energy, likes to take risk, builds relationship with people easily, is able to control quite diverse team, is pragmatic and is efficient at constant risk, can find solution concerning extraordinary situations, is friendly with everyone and is always on his own.

Sensory-ethical extrovert. He is easy to contact, is efficient in group work, is ill tolerate loneliness, tries to find pleasure in life, avoids unpleasant situations, is prone to depressions because of long-lasting problems, communicates well in team, in not prone to deal with science.

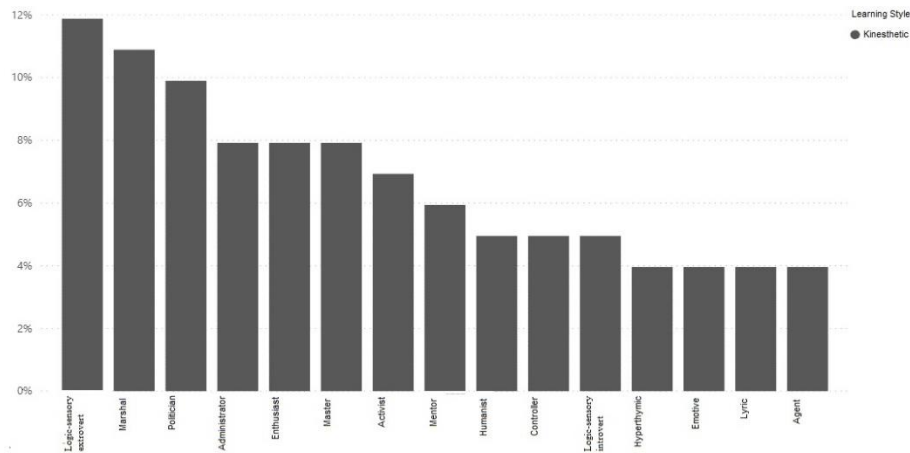


Fig. 8. Number correlation of kinesthetic style students with different psychotypes

Summarizing the data about predominant psychotypes we can consider kinesthetic style students the students to obtain such psychological features as tending to the group(team) activity, planned actions and responsibility. Such analyzing results give reason to determine the most efficient methods to teach students exemplifying collective design method, fulfillment of practice-oriented tasks in small and medium groups, problematic studying. Just these methods to allow own knowledge on practice. With it digital educational content and digital educational tools may be also oriented on team work, task planning, reporting and responsibility for the qualitatively performed work, working out theoretical materials on practice.

Data analyzing module may be also applied for observing interconnections and correlations concerning such measurement as intelligence. Among 7 types of intelligence according to Gardner's theory (Linguistic intelligence, Logical-mathematical intelligence, Spatial intelligence, Bodily-Kinesthetic intelligence, Musical intelligence, Interpersonal intelligence, Intrapersonal intelligence, Naturalist intelligence) concerning our investigation the first and foremost task is to study deeply the features of students majoring in specialty "Computer Sciences" and obtaining such type as Logical-mathematical intelligence.

4 Conclusions

Thus, the data analyzing module within learning styles identification system is one of the most important components to organize adaptive system for students' studying. The proposed OLAP and Data Mining technologies simplify operations with multidimensional data structures aiming on the designed system. Besides, students' special features may be imported into data warehouse to identify fact correlation on one or several measurements.

The results being gained during the experimental work with system and analytical module gave opportunity not only to identify learning style of students majoring in IT specialties, but also to fix correlation between academic achievements, learning style, digital educational content and their psychotype. These results gave the reason to adjust studying methods, to improve digital educational content and to change format for its representation within e-learn courses.

The further investigations will focus on different aspects of educational material representation for the students with different learning styles; developing different type content; developing recommendations concerning educational methods for students with different learning styles.

Besides, for further investigation it is important to take into account special features of social intelligence, because the development of social skills and social intelligence is a relevant problem for modern higher school. After all, the skills of efficient communication and cooperation within global society determines human success.

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Using Game Dev Tycoon to Develop Professional Soft Competencies for Future Engineers-Programmers

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Abstract. The article presents the possibilities of using game simulator Game Dev Tycoon to develop professional soft competencies for future engineer programmers in higher education. The choice of the term “gaming simulator” is substantiated, a generalization of this concept is given. The definition of such concepts as “game simulation” and “professional soft competencies” are given. Describes how in the process of passing game simulations students develop the professional soft competencies. Professional soft competencies include: the ability to work in a team; ability to cooperate; ability to problem-solving; ability to communicate; ability to decision-making; ability to orientation to the result; ability to support of interpersonal relations; ability to use of rules and procedures; ability to reporting; ability to attention to detail; ability to customer service; ability to sustainability; ability to the manifestation of professional honesty and ethics; ability to planning and prioritization; ability to adaptation; ability to initiative; ability to Innovation; ability to external and organizational awareness.

Keywords: simulator; game simulator; competence; professional competence; professional soft competencies; engineers-programmers.

1 Introduction

In the conditions of developing a system of pedagogical education and the introduction of innovative technologies into the process of learning [14; 28], the problem of quality and efficiency of the educational process becomes of particular importance. Over the past few years, the labor market has seen an increase in demand for highly motivated and highly skilled software engineers. One of the important directions in the development of the digitalization of education is the newest computer technologies. Availability, intensification of the learning process, feedback are significant advantages of these technologies, which determined the need for their application in various fields of human activity, especially those related to education and vocational training. At

present, the number of studies has grown significantly, the subject of which was the use of ICT in education.

Compared to other fields, such as medicine or aeronautics, future software engineers begin their professional lives with a serious lack of real practical skills. Therefore, professionals must develop their skills and experience working in real projects, where the consequences of inadequate planning or incorrect decisions can lead to the failure of the entire project or the loss of a significant part of profits [6; 30].

Typical education of software engineers lacks practical mastery of software development processes. Usually, students are presented only with relevant theories of software development processes in lectures, and opportunities to put these concepts into practice while studying the relevant disciplines are quite limited [20].

While most approaches to the training of future software engineers are aimed at adding realism to practical lessons in the classroom, some authors (Márcio de Oliveira Barros [9], Alex Baker [4], Cláudia M. L. Werner [9], Alexandre R. Dantas [9], Emily Oh Navarro [20], André van der Hoek [4]) argue that the only possible way to gain experience in real-world software development processes in academia is to use game simulators in combination with lectures and educational projects.

In addition, while the above approaches differ in terms of the processes they mimic and their specific goals, they are all designed to allow students to better practice and participate in software development processes on a larger scale and in a faster way than can be achieved based on actual projects.

That is why the question of using game simulators for the formation of professional soft competencies of future software engineers arises.

2 Literature Review

Experts and scientists justify the importance of the introduction of information and communication technologies (ICTs), in particular, game simulators, in education [9]. Alexandre Dantas, Emily Oh Navarro, André van der Hoek think, that ICT are included in all spheres of human activity, they also have a positive impact on education, as they open up opportunities for the introduction of completely new methods of teaching and learning [4].

The question of the formation of professional soft competencies for future programmers-engineers is presented in the works of Faheem Ahmed [1], Ritika Atal [3], Lisa L. Bender [5], Kunal Bedse [13], Alejandro Calderón [6], Craig Caulfield [7], Fabian Fagerholm [5], Mehdi Jazayeri [12], Shanika Karunasekera [13], Stanislaw Paul Maj [7], Jürgen Münch [5], Emily Oh Navarro [20], Kendall E. Nygard [5], Kateryna P. Osadcha [15], Max Pagels [5], Mercedes Ruiz [6], Serhiy O. Semerikov [26], Andrii M. Striuk [31], Ashish Sureka [3], David Veal [7], Gursimran S. Walia [5], Jianhong Xia [7] et al.

According to a study by Khaled El Emam [10], the biggest problem of software development projects (SDP) is a rather high percentage of unsuccessfully completed projects, that is, completed incompletely or with budget overheads, or due to lack of certain capabilities and functions.

Goparaju Purna Sudhakar, Ayesha Farooq and Sanghamitra Patnaik found that 70% of SDP failed [23, p. 187]. The high percentage of failed SDP results in the fact that organizations and companies that are customers of SDP do not receive the full benefit of projects.

According to research by Paul Clarke and Rory V. O'Connor, another disadvantage for such companies and organizations is that they do not receive the appropriate return on investment (ROI). Scientists point out that several factors lead to the failure of the SDP: insufficient user participation, as well as senior management in project development; unsuccessful project management; low leadership qualification and low level of understanding of available technologies [8, p. 433]. In particular, the researchers note that the main factor in the failure of the completion of the SDP is the lack of professional competencies in project participants, in particular, in program engineers, or their low level of ownership [22; 29].

According to Ali Noudoostbeni, 67% of SDP failed due to an insufficient level of professional soft competencies of project participants [21].

Emmanuel S. Mtsweni, Tertia Hörne and John Andrew van der Poll have been established that professional competencies are important for the successful completion of the SDP, completion of projects on time, within the budget and with all the necessary capabilities and functions. Researchers distinguish three main professional soft competencies for software developers: teamwork, professional integrity, and ethics, as well as collaboration [19, p. 150].

In turn, teachers are also faced with similar, and possibly even more complex, problems: how to prepare highly skilled programmers-engineers. The challenge is related to the problem of how to train programmers-engineers, which changes over time, as learning technologies, educational programs, and requirements for the learning process are constantly changing [16; 17; 32].

Soft and hard ("solid") competencies are needed for effective professional work. Dave Hodges, Noel Burchell, Elizabeth Rainsbury and Mark Lay believe that professional soft competencies control and determine the behavior and performance of professionals. Authors identify the terms of soft competencies and soft skills [11; 24].

The purpose of this article is to show the possibilities of using the gaming simulator Game Dev Tycoon to form the professional soft competencies of future engineers-programmers.

3 Results

According to a study by Louise Sauv e, the game, in its formal definition, is purposeful competing activity that includes one or another form of conflict (the conflict is represented in the form of an obstacle that does not allow the player to easily achieve the goals of the game) and is conducted within certain agreed rules [25]. The game is attended by at least one person (player) or a group of people (players) who in the context of this game need to make certain decisions to achieve the goal.

Mariya P. Shyshkina in her classification of learning tools allocates a microcosm, in which "the modeling and representation of objects in the subject field, their properties

and relations, object manipulation, changes in their properties, etc., the study of the interconnections between properties” [27].

According to Maryna V. Artiushyna, for didactic purposes, games are divided into “those used to study the new material, the activation of cognitive activity, the consolidation of assimilation of information, verification of assimilation” [2].

Iryna M. Melnychuk offers her classification of interactive gaming technologies for higher education. According to this classification, didactic games are divided into the simulation and role-play [18]. Among the role-playing games, the author highlights simulative-role situations in which students can associate themselves with a certain person whose role they perform, put themselves in the position of this person in certain circumstances, enriching their life experience, will help to acquire practical skills in the specialty, which would stimulate students to consciously master the knowledge and creative use of acquired skills and abilities. At the same time, as the scientist emphasizes, the process of fulfilling a certain role in simulative virtual-professional interactive games involves gaining a sense of self-confidence, verification-belief in the results of his professional training, and hence the readiness to perform professional functions [18].

In this study, under game simulators, we will mean interactive programs that fully or partially simulate certain real processes or systems that capture and motivate students through fun and interesting game experiences, where students can perform different roles in a variety of realistic circumstances and are used in the educational process. when the real practice is impossible or inaccessible.

As a consequence, in this study, the term “game simulation” determines the work of the corresponding game simulator, complete or partial simulation of the corresponding real processes or systems.

We also note that in this study, under professional soft competencies, we will understand a complex of non-specialized competencies that in one way or another relate to problem solving, interaction between people and responsible for successful participation in the work process, high productivity and, unlike specialized competencies, not related to a specific area, control of equipment and technical skills. They cover such aspects of behavior: cognitive competence (situational awareness, decision-making, error management, etc.) and the competence of interpersonal communication.

Game Dev Tycoon is a gaming business simulator that simulates the activity and process of managing a game development company. This game simulator offers an attractive user interface as well as interactive and appealing game play. In Game Dev Tycoon (Fig. 1), students take on the role of owner and manager of their own software development company. At the beginning of the game simulation, students are independent software developers working on their own. As their software development studio becomes more successful, more and more opportunities are available to expand business with several employees and on a larger workspace.

In Game Dev Tycoon, at the beginning of the game simulation, students are independent developers of games that work on their own. They start with the process of developing simple games for different platforms in the virtual garage, as shown in

Fig. 2. As games become profitable, players move into a new office and can hire and train their employees, as well as focus on research, project selection, and contracting.



Fig. 1. The graphics interface of the game simulator Game Dev Tycoon



Fig. 2. The virtual garage in game simulator Game Dev Tycoon

The use of the game simulator Game Dev Tycoon is worth the teacher to include in the curriculum in the amount of 10% of the total score for the subject. The purpose of this game simulator is to supplement the experience of group work that students have learned in the process of learning and developing their group project and thus allow each programmer to lead the development team and manage the SDP. Students should go through the game simulation in Game Dev Tycoon for four weeks and weekly to reflect on the lessons learned and discuss it with the teacher and other students.

Gaming simulator Game Dev Tycoon offers many basic project management elements. During the game simulation, students can go through three main stages of the company's development, namely:

1. Stage of the garage.
2. Stage management team.
3. Stage of world domination.

In these three phases, students have to deal with three relevant project and team management areas, namely:

- a. the process of developing high-quality innovative game applications;
- b. the growing process of hiring, training and managing within a development team;
- c. establishing and maintaining appropriate marketing, sales, and innovation research processes.

Game Dev Tycoon has many details and variations that make it attractive, realistic and interesting for students.

For example, the stage in the garage requires students to focus on creating high-quality games for popular gaming platforms. At this stage, the emphasis is on the continuous production of high-quality innovative games, which requires students to constantly address the design and testing issues of gaming projects, as well as focusing on the latest industry news to identify the industry and market trends.

At the stage of managing a team of growing projects, students will have to go through recruitment/dismissal, training and management teams of software development. A high level of awareness of the competencies of hired employees will be required for students to optimize the time to develop gaming projects of due quality.

Finally, the stage of world domination requires timely and thoughtful management of all aspects of the project, such as developing, debugging, testing software, hiring employees, attending industry conferences, dealing with users and fans, and marketing. The main tasks of students at this stage range from managing a large team of software development to optimizing its cost and choosing the right direction for advancing created game projects, as shown in Fig. 3.

It is also important to have an ethical component of the business process: the players can be questioned by the subjects who offer their services to incite sabotage in the competing companies or offers industrial espionage for additional benefits. So, students are specifically offered to think about aspects of ethical choices and to practically consider the ethics of utilitarianism, the ethics of Immanuel Kant and the prospects of choice. For example, in Fig. 4 shows the suggestion of sabotage.

Another interesting feature of Game Dev Tycoon game simulation is that the company can get loans from banks if the developed game projects were not successful. If the company can not return the amount received within a certain period, then it is declared bankrupt and the game simulation ends. Game Dev Tycoon covers a large number of aspects of PRP management and leadership. At the same time, the intuitive realistic user interface of this game simulator makes it attractive and interesting for students.



Fig. 3. Evolution workspace in the game simulator Game Dev Tycoon



Fig. 4. Proposition of sabotage in the game simulator Game Dev Tycoon

Let's describe some features of this game simulator.

Each project in this game simulator begins with the fact that students are planning to develop a new game. They set the theme, genre, and platform of the game, and then add several technologies that will be used when developing the game (for example, "2D-interface" and "mouse support").

During the game simulation, players can manage the levels of the three main game qualities in each of their projects, namely: the quality of the game process, the quality of the game core and the quality of the game plot being developed.

When project development begins, participants need to set certain priorities for developing the game, allocating the appropriate percentage of working time and distributing the available resources between the development of the game process, the game core, as well as the game plot (Fig. 5). At this stage, the choices made by students and their success depend on the combination of the genre and the themes of the game already selected. For example, the focus on the kernel is considered to be more effective for games such as Sim City, while gameplay and script are more important for role-playing games. Players need to experiment, to learn and understand which combinations are more beneficial and will lead to the success of the project.

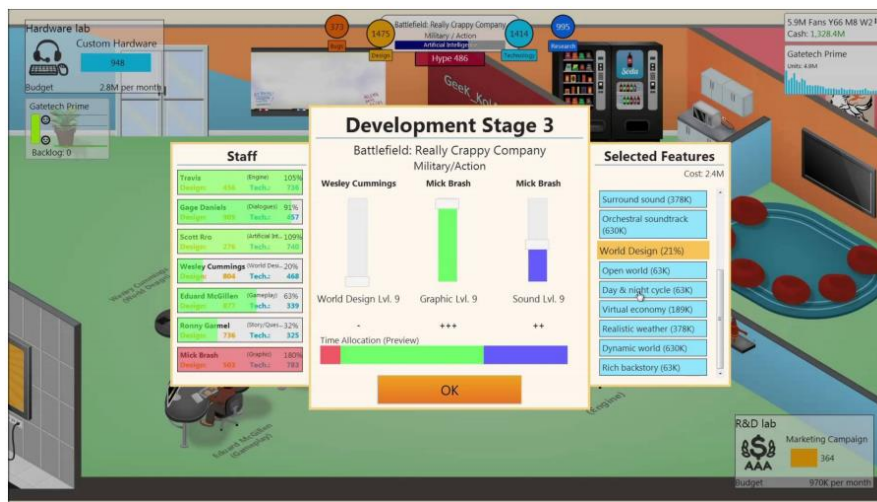


Fig. 5. The Priority Dialog for Game Dev Tycoon

If a company already has several employees, then in the process of developing the game, they can be secured by creating different parts of it, and, importantly, their features and competencies will determine how effectively they perform the tasks.

The project development process is illustrated in graphically small areas that appear alongside the staff and indicate the levels of the two main components of the game: its design and technology. As the project progresses, these two indicators indicate to students how well the process of developing the game is. These indicators do not have a clearly defined scale, but one should understand that the larger the number is better for the project. Using these indicators, players know how well they are playing the game simulation, and as a result, they can challenge themselves to work even better and make more effective decisions when designing the following projects.

Students can choose, game projects that will be released with errors or it's time to postpone the release date and invest more time in fixing them. The three main game qualities above, as well as the platform for which the game is being developed, affects

game rankings and how well it is sold. Throughout the entire gaming simulation, news updates appear on new gaming platforms, as well as reports of major industry events that may affect the gaming simulation, for example, the release of the new Ninvento gaming platform, as shown in Fig. 6.



Fig. 6. Exit Ninvento new gaming platform in the game simulator Game Dev Tycoon

When the project is ready for release, it generates a series of reviews, as well as general remarks about the game, such as “This game is fun” or “Needs improvements”. Previous player experiments around the genre and themes of the game can be noted with such comments or reviews as, for example: “This combination of genre and theme works very well,” and students may also be given feedback if the selected priorities were correct (or vice versa – unsuccessful) with the following comments: “The orientation of the game on the design of the world was not quite successful”. This feedback, as well as a counter indicating how the game is sold over time, allows the player to analyze their achievements and helps to quantify the effectiveness of decisions made by students in the process of developing this project. This encourages students to try again if the selected combinations and decisions are not optimal, or to achieve even better results if the project was still successful.

During the game simulation, students can create and maintain an active base of fans, as well as solve piracy issues. With experience and a good team, they can produce larger and more sophisticated gaming projects. It is worth noting that big projects also bring new challenges, that is, players need to manage a larger team and solve new more complex problems for the release of game hits.

Successful progression in gaming simulation will allow students to choose not only typical projects but also unlock new objects in a game simulator, such as a marketing department, open up innovative research labs, and choose projects that change the

industry. This gives the participants a sense of satisfaction, a certain achievement, and also allows you to gradually unlock new tactical approaches that allow you to experiment with new tools and features. All this makes the process of game simulation not monotonous, but on the contrary – more exciting. Also, players can be presented with several secret projects that can be selected in certain circumstances.

When opening a marketing department, students should understand that in Game Dev Tycoon, marketing is understood to mean any activity that aims at or advancement of a developed gaming project, or market analysis before the development of the project.

When passing gaming simulations in the Game Dev Tycoon game simulator, students develop the following professional soft competencies:

- *Ability to work in a team* – in the process of game simulation, students must work together with their employees to achieve common goals. Students need to be actively involved in team tasks and involve other team members in the work. During the game simulation, students should take into account the feedback from colleagues appearing in replica bubbles and take into account their proposals to achieve common goals.
- *Ability to cooperate* – students need to identify, organize and maintain mutually beneficial relationships not only within the team but also beyond their borders, for example, with virtual clients when discussing software requirements for the successful game Dev Tycoon game simulations.
- *Ability to solve problems* – in the process of game simulations students often have to deal with problems that arise during the development of software, identify options for their solution, assess the strengths and weaknesses of each of the options and make decisions based on their knowledge, abilities, skills, and experience. Students also need to analyze and take into account the various factors and information received from employees, customers and other sources.
- *Ability to communicate* – in the course of game simulations, students are responsible for clear and effective communication, and also take responsibility for the understanding of others.
- *Ability to make decisions* – students must take into account costs, benefits, risks, and chances of success in the decision making process, make logical conclusions based on facts in complex and ambiguous situations, and also make informed, timely, and timely decisions to complete the tasks in the game simulator, effective solutions, taking into account only the necessary data.
- *Ability to focus on the result* – Game Dev Tycoon game simulations are constructed so that students need to use metrics and indicators to achieve their goals and outcomes, make decisions and effectively involve employees in the process of achieving goals (by identifying their strengths and distributing tasks between them) so that the projects remain within the set goals and the budget.
- *Ability to support interpersonal relationships* – in the process of passing game simulations students are constantly faced with the need to maintain positive relationships with other people. Another important aspect is that students are constantly demonstrating examples of constructive discussion of problems, options

for professional responses to certain situations, examples of professional communication with employees and customers based on understanding, courtesy, tact, empathy, care, and courtesy.

- *Accountability* – is the process of passing gaming simulations in Game Dev Tycoon, students must take responsibility for the positive and negative results of the virtual team's work and report their achievements and failures to the teachers during the learning process.
- *Sustainability* – in gaming simulations, students need to maintain high productivity and self-control under pressure and in times of trouble for successful completion of tasks.
- *Ability to demonstrate professional integrity and ethics* – in the process of game simulation students can ask questionable industry subjects, so students are specifically invited to think about aspects of ethical choices. Students also need to deal with piracy issues during game simulation. To complete the game simulation, students need to be educated and contribute to maintaining the desired behavior by the existing standards of organization and society.
- *Ability to plan and prioritize* – students need to set certain priorities for the development of the game, allocating an appropriate percentage of working time and distributing available resources between the development of the game process, the game core, as well as the game plot.
- *Adaptation ability* – students must constantly pay attention to the latest industry news, identify trends in the industry and the market, adapt quickly to change, and easily consider new approaches to software development and business conduct, to complete the game simulation.
- *Ability to take the initiative* – the Game Dev Tycoon game simulator requires students to actively identify existing opportunities and challenges, search for maximum benefits, and solving the problems. To complete the simulation, students need not lose their opportunities to achieve their goals.
- *Ability to innovate* – the successful passing of the simulation requires students to experiment a lot to learn and understand which combinations are more beneficial and will lead to the maximum success of the project. Students also need to open up innovative research laboratories and select projects that change the industry for the successful passing of game simulation.

To test the efficiency of this game simulator for the formation of professional soft competence software engineers were involved in 95 and 88 students (control group (CG) and experimental group (EG)).

In the experimental group, students were trained using this simulator, and in the control group, the training was conducted by typical traditional learning conditions.

Formation of control and experimental groups was carried out based on the results of preliminary testing in such a way as to ensure statistical correspondence of the level of knowledge of students of control and experimental groups.

During the period of implementation of this simulator in the educational process, the observation method was applied, the essence of which is that during practical classes the teacher observes the activities of students in a specific model of a game simulator

and discusses the result with the student on the results of the generated report. The final grade for the practical work was presented taking into account the personal point of view of the teacher, which he formed during his observation of the student.

The levels of professional soft competency formation were determined based on final testing within the discipline “Professional Practice of Software Engineering”.

Let us present a statistical analysis of the results, which was carried out taking into account the comparative study strategy. The comparative method was implemented by comparing the results of the experimental and control groups in the study process. The comparative distribution of students according to the assessment of professional soft competency formation in the control and experimental groups at the beginning and the end of the experiment for each competency is shown in Fig. 7.

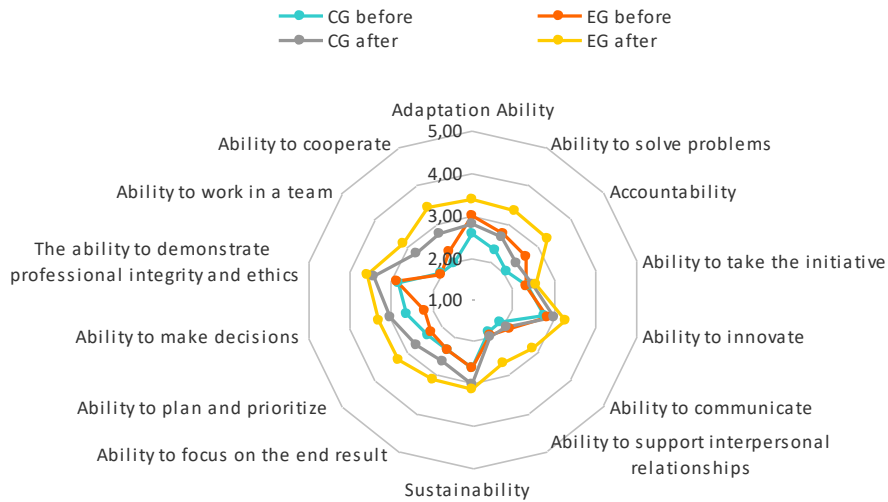


Fig. 7. Average assessment of the level of professional soft competencies of students in CG and EG at the beginning and end of the experiment

The comparative research method allowed us to trace the positive dynamics of the formation of professional soft skills in the application of the game simulator Game Dev Tycoon.

All competencies were divided into three criteria, for each of which were calculated Pearson χ^2 criterion. Since $\chi^2_{exp} > \chi^2_{critical}$ for each of the criteria, the results suggest that the higher level of professional soft competencies of students is the result of the introduction of the game simulator Game Dev Tycoon in the training of future software engineers.

That's why efficiency of the formation of professional competence soft software engineers increase significantly when used game simulator Game Dev Tycoon in training future engineers-programmers.

4 Conclusions

In the process of using this game simulator in the learning process, future professional engineers develop the following professional soft competencies that they need in their further professional competencies: ability to work in a team; cooperate; problem solving; communicative; decision-making; orientation to the result; support of interpersonal relations; use of rules and procedures; reporting; attention to detail; customer service; sustainability; the manifestation of professional honesty and ethics; planning and prioritization; adaptation; initiative; Innovation; external and organizational awareness.

It is statistically confirmed that the efficiency of the formation of professional competence soft software engineers increase significantly when used game simulator Game Dev Tycoon in training future engineers-programmers.

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Formal Approaches to Identify Cadet Fatigue Factors by Means of Marine Navigation Simulators

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Abstract. Contemporary marine education tends to have been using navigation simulators enabling cadets to be trained for any unlikely event. These issues are sure to be in the sector with high demand focusing on safety. Thus, they would be extremely beneficial for marine industry. The proposed study aims to identify seafarer fatigue during the maneuver carrying out according to circumstantial evidence and, as a result, the influence of this phenomenon on the trajectory formation of transition or maneuver experiences. In addition to it, the method of cadet posture identification is generally revealed. To summarize all this information exo – back spine and an automated system are proposed to be used. The study provides the mechanism formation of spatial trajectory taking into account the identification of fatigue indicators. This issue will, eventually, benefit into reducing risks of accidents. Besides, a formal description of perception and decision-making processes being performed by the cadet by means of modal logic and algebra of events are introduced in the preceding article. It is a basis for determining the stages and individual preferences in the formation of the trajectory transition (maneuver). To make ground, the experiment within the framework of analyses of the mooring operation carrying out is sure to be named an effective one. This article proposes comprehensive approaches and provides the possibility to classify models for the formation of the trajectory of the cadet in conditions of fatigue crack factors.

Keywords: human factor, fatigue factor, support decision making, trajectory cadet behavior

1 Introduction

It goes without saying that fatigue indicator (both among cadets and professional navigators [1-4]) are named to be one of the most significant causes of negative human factor influence in maritime transport. Contemporary studies have been trying to

contribute to finding the appropriate way out focusing mainly on the control of robot modes while having a navigational watchkeeping practice [5-6]. However, there are no inquiries embracing direct fatigue indicators of cadets while watchkeeping carrying out in real time mode. Meanwhile, a number of psychological and medical investigations implemented in this field has turned out to be reflecting the heterogeneity of the fatigue manifestation during a certain period of time [7-8]. These issues are highly likely to be contributing to the significant augmentation of the uncertainty degree in scientific search.

This following article would like to introduce an alternative method of cadet fatigue identification during the complex navigation tasks performing on the captain's bridge. They would be mostly based on circumstantial pieces of evidence [9-11]. In the course of the experimental analysis of the behavior of the cadets – navigators, reported to have been carried out for four years, several issues had been drawn attention to, such as the posture when working with navigation devices, the reaction rate when performing primary actions etc. Furthermore, the sensors applying (i.e. accelerometers in the form of exo – back spine) have triggered in significant facilitation of cadet posture identification in space in real time mode [12]. The particular details must be added to the fact regarding the accomplished automated analysis of micro-reactions which enormously simplified the implementation of an individual approach to result interpretation.

2 Materials and method

In this context, the exo – back spine is said to be a dynamic system being defined in accordance to a number of parameters. Data parameters can be represented as system limiters. Considering this approach to exist within the framework of formal research [13], the most significant components of the system can be named as: l the angle of distortion between adjacent shoulders relative to the exo – vertebra cadet during the maneuver; m is the complexity of the maneuver; H is the fatigue coefficient at a given time i .

Then this set of components, $\xi = \{l_i, m_i, H_i\} \in \Xi \subseteq E_N, i = 1, \dots, n$ could possibly occur in the presence of a circumstantial factor model of the $\omega = q^0 \in Q | q = (q_1, \dots, q_n) \in Q_n$ representing the initial position of the exo – back spine of a cadet in space [14]. However, unlike artificial spine systems the dynamic one of a cadet is noticed to be unable to correspond to a formal gradient model such that: $g(\omega) = (q^0, 0) \in E_{2n}, \Phi^0(\xi, z) = C \|z\|^2$ phase system vector, $z = (q, \dot{q}) \in Q_n \times \dot{Q}_n, z = Z \subseteq E_{2n}$ and penalty constant C .

It can vividly be observed that within each definite time span system parameters may vary nonlinearly in accordance to having physiological characteristics of the cadet. He is being influenced by a number of external and internal factors. So, to be precise, the position of the cadet is engaged in providing a great possibility for an automated system to detect and to deliver the information about what type of a navigation device is being operated with.

Therefore, when a number of similar situations happens to be, it is reasonable to state that one or another posture deviation has a high likelihood of being looked at as normal but only for a short period of time. It is mostly due to the dashboard which is being located underneath.

At the same time, there are other factors sure to be noticed directly influencing on psycho-emotional state of the cadet (i.e. pulse and temperature of body combined with the speed of performing manipulations with joysticks, buttons and touch panels ECDIS, ARPA, GPS and others) [15] (Fig. 1).

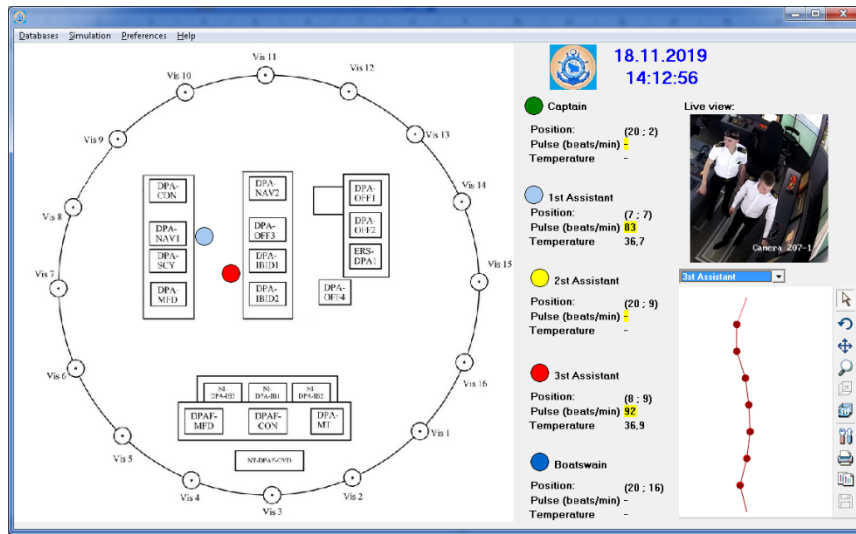


Fig. 1. Identification interface psycho-emotional state of the cadet

Furthermore, according to [16, 17] a plan constituting a number of stages of the impact of $u = \{u \in E_n || u_i \leq u'_i, i = 1, \dots, n\}$ on ship specific control objects $u(t) \in V$ let the cadet be aware of every action afterwards. So, defining the set of the valid running impact made by the cadet in the form of $X \times Y, x \in X$ such that $Y(x) \subseteq Y \subset E_m$ the model of $q(x) = \max_{y \in Y(x)} f^0(x, y) \rightarrow \min_{x \in X}$ possible to be taken as being the true one, where y represents the vertical axis of the exoskeleton, and x does the horizontal one (Fig. 1).

Suppose, that a cadet is performing a maneuver and trying to make a use of navigation devices and controls. It goes without saying that he defines for himself the trajectory and sequence of transitions due to his having had experience and acquired behavior patterns in similar situations. So, it is worth emphasizing that this is the predominant way of action plan shaping recognized as being the most productive and valuable one in a particular situation [18].

By all means, there are several other approaches allowing transition paths to be identified and individual sequence of actions to be checked [19]. Notwithstanding, there is another challenge to make a stand against that is noticed to be a problem of

comparison and classification of such trajectories. As well as this item the performance measurement at the early stages of the maneuver is to be spoken about.

The following article presumes that a solution has been reached through the idea of taking the main factor allowing to identify trajectories causing risk as a time indicator of interaction with navigation devices or controls. It must be noticed that attention switching from one to the next in the chain trajectory objects is highly likely to take no more than 1 second. It depends mostly on the complexity of the maneuver and qualifications of a navigator.

Conducted experiments of TRANSAS NAVIGATIONAL SIMULATOR NTPRO 5000 of Kherson State Marine Academy (Ukraine) provided substantial opportunity to come up to the conclusion that skippers' behavior patterns turned out to have been inherited and transformed rarely into new forms. These issues depend mostly on location and weather conditions. It must be noticed that only experienced sailors were involved into the spoken above experiment. So, therewith, at the same time, the fatigue factor must be taken into consideration as being the main and significant contributor of any changes in cadet behavior. It is due to the fact that it is completely different from other factors from the point of view of applied strength and degree of influence upon the final result.

A proper formal description of events and trajectories of transitions between ship management facilities and navigation data sources is proposed to apply the logical-event algebra of events. It happens to have approaches which can properly describe the behavior of the cadet under severe conditions [20].

Let's consider this approach applying basing on this experimental data by means of analyzing log files from the server of the English channel simulator location. So, the transition trajectory can be characterized by 9 stages, each of which is precisely determined either by fixing awareness time or by time spent on controlling manipulations (i.e. steering, machine telegraph, thrusters, navigation signals, etc.).

It must be reported that the number of trajectories of carrying out of the typical maneuver actions performed with an aim to determine the cadet behavior model is to be approximately a minimum from 5 to 9. To meet the spoken above requirements 11 trajectories were taken to be analyzed. In addition, we are to underline that one and the same navigator was chosen to be experimented upon with an issue to perform a typical maneuver action in various locations.

Maneuver from mooring operation was paid attention. To a certain degree, the figure provides the opportunity to watch the time ranges of work with objects of the trajectory having 2-3 levels of deceleration. This fact is said to be the index of having nonrandom contributing factor affecting the transitional indicator of the maneuver performance.

Besides, the convenience of having this trajectory visualization in the form of a graph should be additionally italicized and, so, let's describe the exact peculiarities of its construction. Graph variables represent an integral index of being ready for the stage maneuver s_i implementation depending on the identified fatigue. This data is based on indications of exoskeleton curvature and individual threshold perception of navigational danger:

α is the reaction of a quick transition to the next element of the trajectory;

β is an indicator of fatigue during posture curvature;

γ is an indicator of fatigue when the reaction is getting to slow down.

The transitions between the stages of the trajectory s_i can be one directional in the case of α reaction and the reverse ones in case of having β or γ .

Having experimented permitted to identify several types of situations to speak about as the cadet returning to the element of trajectory. It is mostly due to having lacked of perceived information or due to the changes in management strategies. We are sure to underline the idea of demonstrating of the mentioned above behavior pattern as being typical or distinctive one in the conditions of implicit action plan formation for a certain period of time [21].

The aim of the study is stated to introduce the automated identification process scheme of such types of phenomena that will provide the ability to determine the human factor influence with the help of implicit indicators. For the implementation of more detailed analysis we wanted to find out and offer the levels of stage characterizing the cadet interaction with navigation devices and objects of location. These levels will be varied according to complexity starting from the least difficult l_1 to the most time-consuming ones l_4 : l_1 which is visual perception of the situation; l_2 is analysis of current data of navigation devices; l_3 is performing maneuvers (steering, machine telegraph, thrusters, navigation signals, etc.), l_4 is discrepancy with goals, mooring, computation of complex maneuvers (Fig. 2).

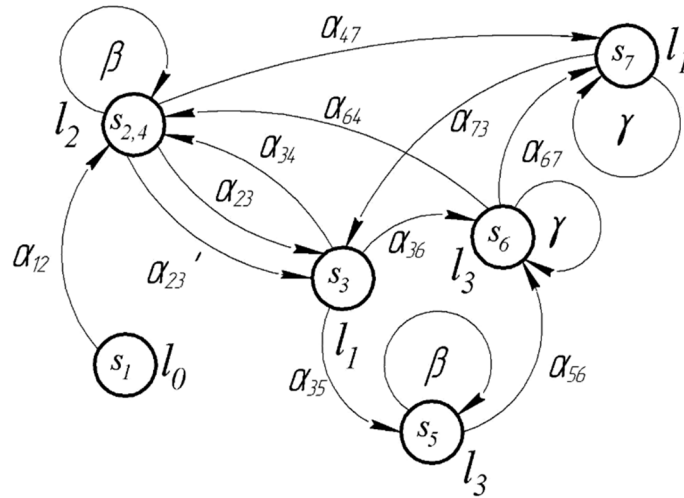


Fig. 2. Difficulties in defining variables in a classical graph

The metric for representing a graph on the flat is limited by discrete axis l_i and continuous axis t_i which determines the time Δt gaps between the steps of the trajectory s_i (Fig. 3). Let's have a quick look at what kind of issues can be described by the direct transition matrix.

$$S_{ij} = \begin{matrix} \emptyset & \alpha_{12} & \emptyset & \emptyset & \emptyset & \emptyset & \emptyset \\ \emptyset & \beta & \alpha_{23} & \emptyset & \emptyset & \emptyset & \emptyset \\ \emptyset & \emptyset & \emptyset & \alpha_{34} & \alpha_{45} & \alpha_{36} & \emptyset \\ \emptyset & \emptyset & \alpha_{23}' & \emptyset & \emptyset & \emptyset & \alpha_{47} \\ \emptyset & \emptyset & \emptyset & \emptyset & \beta \vee \gamma & \alpha_{56} & \emptyset \\ \emptyset & \emptyset & \emptyset & \alpha_{64} & \emptyset & \gamma & \alpha_{67} \\ \emptyset & \emptyset & \alpha_{73} & \emptyset & \emptyset & \emptyset & \gamma \end{matrix}$$

Constructing transitions in the trajectory due to the introduction of β and γ as well as mandatory circumstantial indexes are unable to succeed in this problem solving. A similar problem highly likely to be found out is that the system of equations of the form does not reflect the trajectory in the whole way:

$$\begin{aligned} X_1 &= X_1 S_{11} \vee X_2 S_{21} \vee \dots \vee X_n S_{n1} \vee R_1, \\ X_2 &= X_1 S_{12} \vee X_2 S_{22} \vee \dots \vee X_n S_{n2} \vee R_2, \\ &\dots\dots\dots \\ X_n &= X_1 S_{1n} \vee X_2 S_{2n} \vee \dots \vee X_n S_{nn} \vee R_n. \end{aligned}$$

where X is an event with reference to the trajectory element, S is a i -th component.

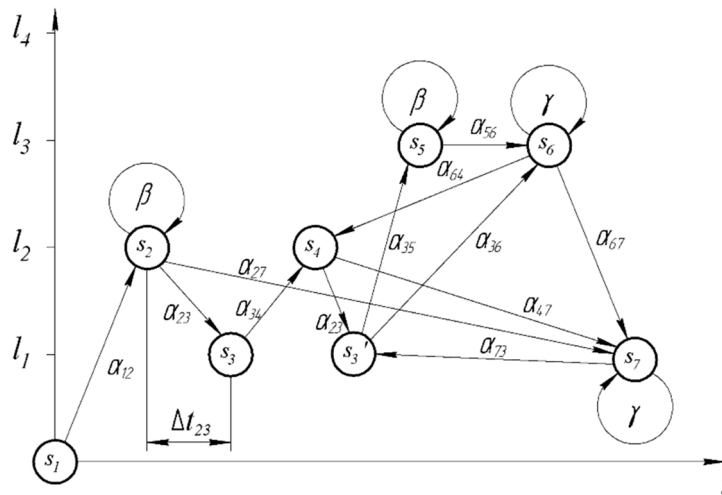


Fig. 3. A detailed graph on a flat in time approximation trajectories of elements in the state space

Thus, based on the spoken above information the study considers the use of the classical graph to be completely impractical due to the idea of being each element of the trajectory no longer the same one as it was being at the moment t_{i-1} . These issues are partially conditioned according to the fact that the cadet fatigue state and spent forces are to have been changing. Therefore, it is recommended to apply the interpretation of the proposed time-spent graph depicted in this figure. The new approach can be treated

like worth taking particularly in the situations where the study is being involved in having temporary intervals for transition. This item is clearly evident in provided information from the article.

Moreover, ordinary interpretation is impossible to be used for indicating the determinant of time if the path element happens to be reversed.

In addition, one more situation to be taken into consideration is when there are one or two variables of priority and time range expressed implicitly. In this case accordingly it is convenient to use the third axis allowing to determine exactly all time intervals regarding active trajectory elements. So, then graphical interpretation will be described by the following geometric system (Fig. 4).

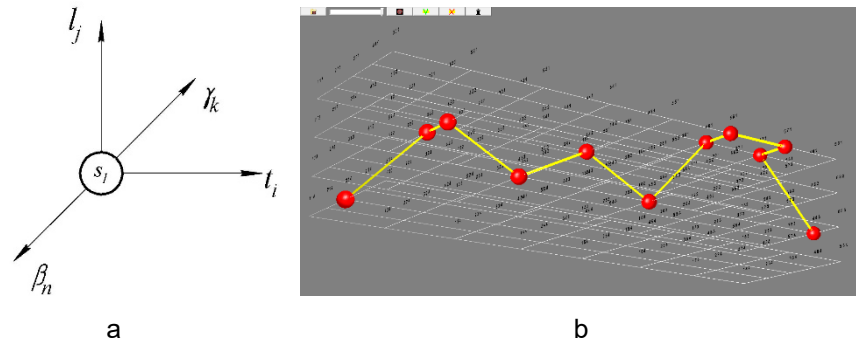


Fig. 4. Three-axis geometric system for constructing a graph

As for a three-axis geometric system for constructing a graph, it could be problematic enough to be described by a graph on a flat not using designed visualization software. To deal with the point, software and tools for visualizing trajectories were created. They met the requirements of matching the implementation of such features as temporary indicators and indicators of fatigue (Fig. 4 a, b).

3 Results

To sum up, trying to find the way out, the automated geometric approximation of the trajectory is primarily proposed. This fact certainly grant you the possibility to control the transition speed between its elements in the form of thickness and time in the form of the diameter of the knot.

Besides, while the experiment was being performed there were several cases associated with increased exacerbation of navigation environment. They are rooting out of the negative influence of relevant factors. As a result, frequent returns to previous trajectory elements were noticed to be done confirming the information about cadet having lost of confidence in his own. Moreover, when the navigation situation is perceived in a much more confident way by a cadet and when he is perceiving the information with a high degree of reliability he comprehends the information peculiarities ψ parameters in node x have $B(x, \varphi)$.

Then at time t_x+1 the formation of connections between different items node x , will be developed basing on the following principles [22-27]:

$$\begin{aligned} L_S(x, \varphi) \wedge \circ B(x, \neg\varphi) &\Rightarrow B(x, \varphi), \\ L_S(x, \varphi) \wedge \neg \circ B(x, \neg\varphi) &\Rightarrow B(x, \varphi), \\ \neg L_S(x, \varphi) \wedge \neg \circ (B(x, \neg\varphi) \Rightarrow B(x, \varphi)) &\Rightarrow B(x, \neg\varphi), \\ L_S(x, \varphi) \wedge \circ B(x, \neg\varphi) &\Rightarrow \neg B(x, \varphi). \end{aligned}$$

Herewith, $K(x, \varphi)$ indicates that the cadet is aware of φ information on node x , i.e. $\circ B(x, \neg\varphi) \equiv \perp$, defining a number of knowledge formation rules.

Thus, to be more precise, the final goal of X is believed to be carrying out of a sequence of action – items of trajectory by cadet, while there are a number of conditions Ψ defining $\square X$ and conditions Φ , defining $\diamond X$. Besides, the passing's of the planned route could possibly be expressed with the intent of $\square G(X, \Phi, \Psi)$:

$$\begin{aligned} \square G(X, \Phi, \Psi) &\equiv B(X, \neg\Phi) \wedge G(X, \diamond\Psi) \wedge \\ &\wedge K(X, [(B(X, \Phi) \vee B(X, \neg\square\Phi) \vee B(X, \neg\Psi))]). \end{aligned}$$

So, in this case, the definite issue possible to be treated to as a successful one is to be said as being without repeated actions towards the elements of trajectory passing's:

$$\begin{aligned} \square G(X, \Phi, \Psi)' &\equiv B(X, \neg\Phi) \wedge G(X, \diamond\Psi) \wedge \\ &\wedge K(X, [(B(X, \Phi) \vee B(X, \neg\square\Phi) \vee B(X, \neg\Psi))\mathcal{U}(G(X, \diamond\Psi))]). \end{aligned}$$

Besides, it is worth speaking that in some situations to cope with a long trajectory it would be beneficial to divide it into homogeneous fragments. They are being characterized by high activity of taken decisions, each of which will be separated by the time interval $t_{(\Delta+m)}$, where m is the number of segments of the global trajectory. At the same time let's take that the primary fragments of the trajectory are supposed to have been overcome successfully. Consequently, the views of the cadet can be identified and described by the conditions in future $\circ G(x, \varphi)$:

$$\circ G(x, \varphi) \Leftrightarrow I(x, \varphi) \wedge K([Do(x, \alpha)], \varphi) \wedge \square Do(x, e),$$

as well as by a specific fragment of trajectories:

$$G(x, \varphi)_{t_{(\Delta+m)}} \Leftrightarrow I(x, \varphi), G(x, \varphi \wedge \psi) \Rightarrow G(x, \varphi) \wedge G(x, \psi).$$

All these items contribute to increasing the level of information perception in the cases when fragments of the trajectory are characterized by the same set of actions of the cadet in the form of beliefs:

$$B(x, \square(\varphi \wedge \psi))_{t_{(\Delta+m)}} \wedge I(x, \varphi) \wedge I(x, \psi) \Rightarrow I(x, \varphi \wedge \psi)_{t_{(\Delta+(m+1))}}.$$

Then the created action plan at the time of $t_{(\Delta+m)}$, that is being expressed in the information model of behavior, $P(x, \cdot)$, where information about the performance of elements $I(x, \varphi)$ trajectory is presented as:

$$I(x, \varphi) \equiv \square G \left(x, \exists e \left[B \left(x, \exists e' (\text{happ.} (x, e'; \varphi)) \right) \wedge G(x, \neg \text{happ.} (x, e, \varphi)) \right]; e; \varphi \right).$$

Cadet perception forms a preference vector P under such conditions:

$\xi \in \{B(\varphi), I(\varphi), G(\varphi), \alpha\}, \varphi \in \mathcal{L}, \alpha \in \Theta_A$, so, that:

$$\begin{aligned} P(x, I(\varphi), I(\psi)) &\Rightarrow I(x, \varphi) \wedge I(x, \psi), \\ P(x, G(\varphi), G(\psi)) &\Rightarrow G(x, \varphi) \wedge G(x, \psi), \\ P(x, G(\varphi), G(\psi)) &\Rightarrow P(x, I(\varphi), I(\psi)) \wedge G(x, \varphi) \wedge G(x, \psi), \\ P(x, G(\varphi), I(\psi)) &\Rightarrow P(x, I(\varphi), I(\psi)) \wedge G(x, \varphi), \\ I(x, \varphi) \wedge \neg \exists \psi | P(x, I(\psi), I(\varphi)) &\Rightarrow G(x, \varphi), \\ I(x, \varphi) \wedge \neg \exists \psi | P(x, I(\psi), I(\varphi)) &\Rightarrow I(x, \varphi) \Rightarrow G(x, \varphi), \\ \neg \exists \psi \left[\left(P(x, I(\psi), I(\varphi)) \wedge B(x, \square \varphi) \right) \right] &\Rightarrow I(x, \varphi) \Leftrightarrow G(x, \varphi). \end{aligned}$$

Meanwhile, in a way, it is obvious that its properties are determined by the following dependencies:

$$\begin{aligned} P(x, \varphi, \psi) &\Leftrightarrow P(x, (\varphi \wedge \neg \psi), (\neg \varphi, \psi)), P(x, \varphi, \psi) \wedge P(x, \varphi, \psi)' \Leftrightarrow P(x, \varphi, \psi)'' \\ P(x, \varphi, \psi) \wedge P(x, \varphi, \psi)' &\Leftrightarrow P(x, \varphi \vee \psi), P(x, \varphi, \psi) \wedge P(x, \varphi, \psi)' \Leftrightarrow P(x, \varphi, \psi \vee \varphi). \end{aligned}$$

Along with it, it should be taken into consideration that factors influencing on the carrying out of the fragment of the trajectory affects the execution of the element in the future – α_i , where α_1 is believed to be the most efficient item from the cadet's point of view then:

$$\begin{aligned} P(x, \alpha, \alpha_1) &\equiv G(x, [Do(x, \alpha)]) \wedge B(x, [\alpha_1 > \alpha]) \wedge B(x, [\alpha_2 > \alpha]) \wedge \dots \\ \dots \wedge B(x, [\alpha_n > \alpha]) &\wedge B(x, \alpha_1 \neq \alpha_2 \neq \dots \neq \alpha_n) \Rightarrow G(x, [Do(x, \alpha)]) \wedge \dots \\ \dots \wedge \left(\neg G(x, [Do(x, \alpha_2)]) \wedge \dots \wedge \left(\neg G(x, [Do(x, \alpha_n)]) \right) \right). \end{aligned}$$

In this regard, initial information φ supposes the performance of ψ knowing K defines:
 $P(x, \alpha, \varphi) \equiv G(x, [Do(x, \alpha)]) \wedge K([Do(x, \alpha)], \varphi)$, such that:

$$G(x, \varphi \mathcal{U} \psi) \equiv P(x, G(\psi), I(\varphi)) \wedge \neg \exists \varphi \left[P(x, G(\psi), G(\varphi)) \wedge P(x, G(\varphi), I(\varphi)) \right],$$

where \mathcal{U} shapes the development of the trajectory in the future.

In this case, φ as a prerequisite for the subsequent performance of a fragment of the trajectory is definitely determined by dependencies such type that:

$$\begin{aligned} G(x, \varphi ST) &\equiv \neg \exists \psi P(x, G(\psi), I(\varphi)), \\ G(x, \varphi S(\psi \wedge \varphi)) &\equiv G(x, \varphi \mathcal{U} \psi) \wedge G(x, \psi S \varphi), \\ G(x, \varphi) &\equiv I(x, \varphi) \wedge \forall \psi \left[P(x, \varphi S \psi) \Rightarrow B(x, \square(\varphi \wedge \psi)) \right]. \end{aligned}$$

This experience is leading to the functioning entrenched system of beliefs in the effective carrying out of the fragment of the trajectory [28]. It goes without saying that when the most challenging emergency situations arise the roles and strategies on the

captain's bridge can be greatly changed. They are causing the significant effect on the formation of the trajectory and become effort-consuming I :

$$\begin{aligned}
& G(x, \varphi) \wedge \neg Af(G(x, \varphi)) \Rightarrow \circ G(x, \varphi), \\
& G(x, \varphi) \wedge \neg Af(G(x, \varphi)) \Rightarrow \neg \Psi(\psi) [P(x, I(\psi), I(\varphi)) \wedge Af(\Psi(\varphi))] \Rightarrow \circ G(x, \varphi) \\
& G(x, \varphi) \wedge \neg Af(G(x, \varphi)) \wedge \\
& \wedge \forall \psi [P(x, I(\psi), I(\varphi)) \Rightarrow \neg Af(I(x, \psi)) \wedge B(x, \Box(\varphi \wedge \psi))] \Rightarrow \circ G(x, \varphi)
\end{aligned}$$

Where $\Psi(\varphi)$, $\varphi \subset \Psi$ is the formation of individual levels of cadet possible perception and his reaction to navigation circumstantial conditions [29].

4 Experiment

Taking into account the peculiarities of performing mooring operations, the most preferable to be used approach is said to be the SS one. The deterministic process of it is envisaged to take place.

Then, the mooring of the vessel s can be described by the following $(w, t | w \in W, t \in T)$, where $w = \langle \Theta_A^w, \Theta_O^w, \Theta_F^w, R_O^w \rangle$. Therewithal, variations of the mooring trajectory of the operations are able to be described by a variety of $S_w = \{(w, t) | t \in T\}$.

General number set of mooring situations are defined as $S = \cup_{w \in W} S_w$, where $s = \dots, s \in S$ and time can be reported by a sequence of actions in the path of trajectory (t_0, \dots, t_k) , $\forall u \in \{0, \dots, k-1\}$, $(t_u | u \in N)$, $(t_u, t_{u+1}) \in R_w$ is considered to be a typical one in the initial stages. Nevertheless, an action plan is being formed at the time of t_{u+1} . As a rule, the initial plan of the development of the trajectory of actions has been formed. However, all possible factors forming its Δ_p are not taken into consideration.

To be precise, exactly these factors will make major contribution towards the supposition of the development of trajectories. We are to mention that it is the information-plan of its carrying out $\beta_1, \beta_2, \dots, \beta_n$ that is formed initially being fragmented as $\Delta_{\beta(t_u)}$. Situation identification $\delta \subseteq S \times S$ depends greatly on restrictions such as $((w, t), (w', t')) \in \delta$ and supposes $(s, s') \in \delta$ as a part of class-forming set Δ_δ .

So, hereby, the result of the variable formation of the trajectory can be described as being very different (Fig. 5 a and b).

In the Figure 5 the changes of strategies of maneuver carrying out $\beta_1 \vee \beta_2$ are vividly reflected. They are being dependable on the limitations of $w', t' \in \delta$ when cadet is involved in choosing the direction and speed of the ship to prevent ship collision.

Let's describe the cadet action plan β aiming to keep the ship in the place while performing mooring operations and pulling it towards the pier using engines. It is given by the predicate $\odot(\beta, p, u, v)$, where p is the way to the complete mooring operation and $[u, v] \in T$ is time intervals allotted for the maneuver carrying out. The time span is to be taken as no more than one hour as the overheating of the thruster is highly likely

to happen [30-33]. Then the trajectory of the mooring task # will be described by the following dependencies:

$$\#(\alpha, p, u, v) \Leftrightarrow (v = u + 1) \wedge (Af(p(u), p(u+1) = \alpha)), \alpha \in \Theta_A;$$

$$\#(\beta; \beta', p, u, v) \Leftrightarrow (\exists n \in [u, \dots, v]) \wedge (\#(\beta, p, u, v)) \wedge (\#(\beta', p, u, v));$$

$$\#(\beta | \beta', p, u, v) \Leftrightarrow (\#(\beta, p, u, v)) \wedge (\#(\beta', p, u, v));$$

$$\#(\beta \parallel \beta', p, u, v) \Leftrightarrow (\#(\beta, p, u, v)) \wedge (\#(\beta', p, u, v));$$

$$\#(\beta^*, p, u, v) \Leftrightarrow ([u = v]) \vee (\#(\beta; (\beta^*) p, u, v));$$

$$\#(s', p, u, v) \Leftrightarrow (s \in (w, p(u))).$$

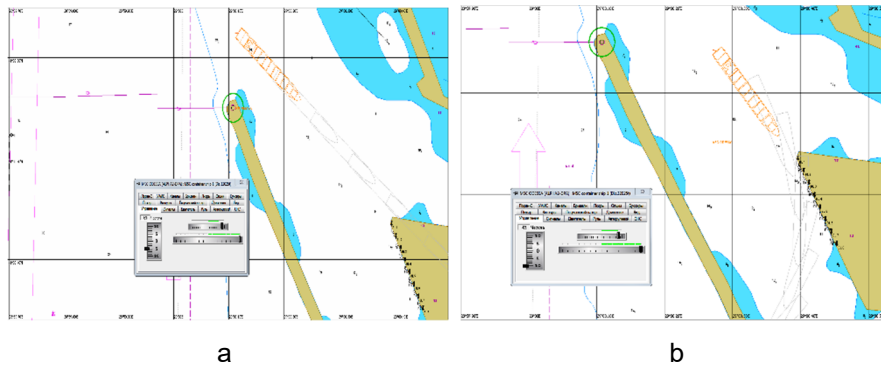


Fig. 5. The variable formation of the trajectory

Thus, the experimental study of the mooring operation provides a sufficiently high possibility to identify the effectiveness of the action plan $\#(\beta, p, u, v)$ (Fig. 6-9):

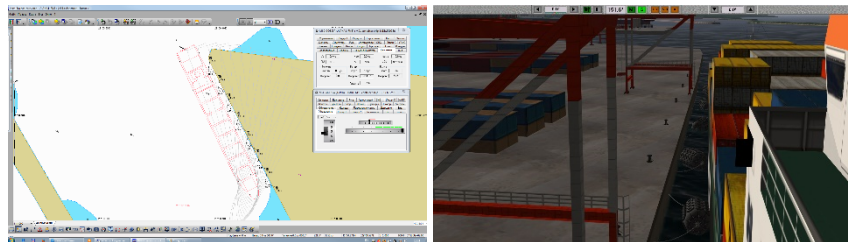


Fig. 6. Time: 07.33.30. When speed is getting to be decreased (reverse small stroke) fixed pitch right rotation rotor lets you shift the stern towards the berth. Having the bow thruster as an assistant bow is replacing to the pier

During the semester an experiment was conducted having 74 cadets involved in participating and performing the typical operation of vessel mooring and demonstrating various degrees of fatigue. The experiment confirmed the research hypothesis as being evident. This issue can easily be proved by the following scheme observation (Fig. 10).

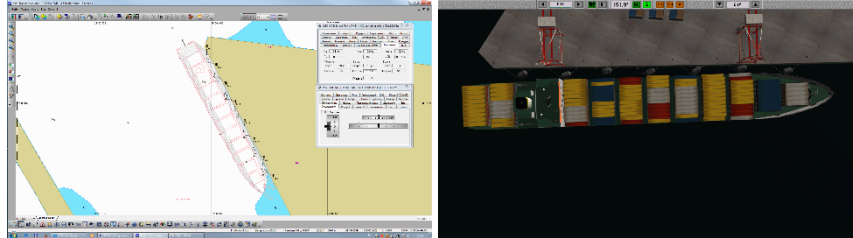


Fig. 7. Time: 07.36.30. The vessel is practically motionless and is located near the berth protection fender

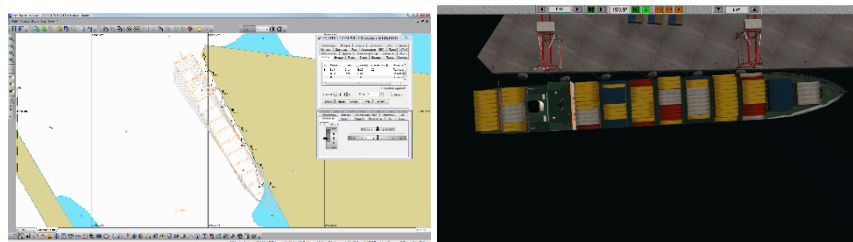


Fig. 8. Time: 07.38.50. Give the head and stern mooring lines

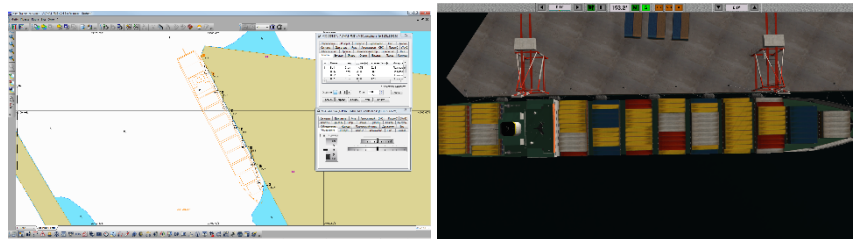


Fig. 9. Time: 07.46.00. Tighten up the head and stern mooring lines, make all fast

5 Conclusion

The experiments are noticed to demonstrate clear evidences of hypothesis confirmation of the formation of class-forming structures in the form of trajectories of transitions being under fatigue factor influence and circumstantial implicit evidences. They can be such as posture abnormalities, speed of movements, and physiological indicators of the cadet. It must be emphasized that proposed logical formal approaches enabled the stages of formation of action trajectories to be differentiated in the form of a plan as well as provided a beneficial possibility to describe an impact of individual behavioral strategies on the final result.

Thus, objective scientific results were obtained:

1. The co-dependency between the navigator's fatigue indices and the spatial position of its spine as a dynamic system determined by a number of parameters was

investigated, and, as a consequence, software identification of navigator posture deviations was proposed to be used.

2. The approaches for shaping the navigator's trajectory of behavior by means of a 3D structured space during the maneuvering of the vessel were proposed. This fact delivered the possibility to take into account his fatigue factor.

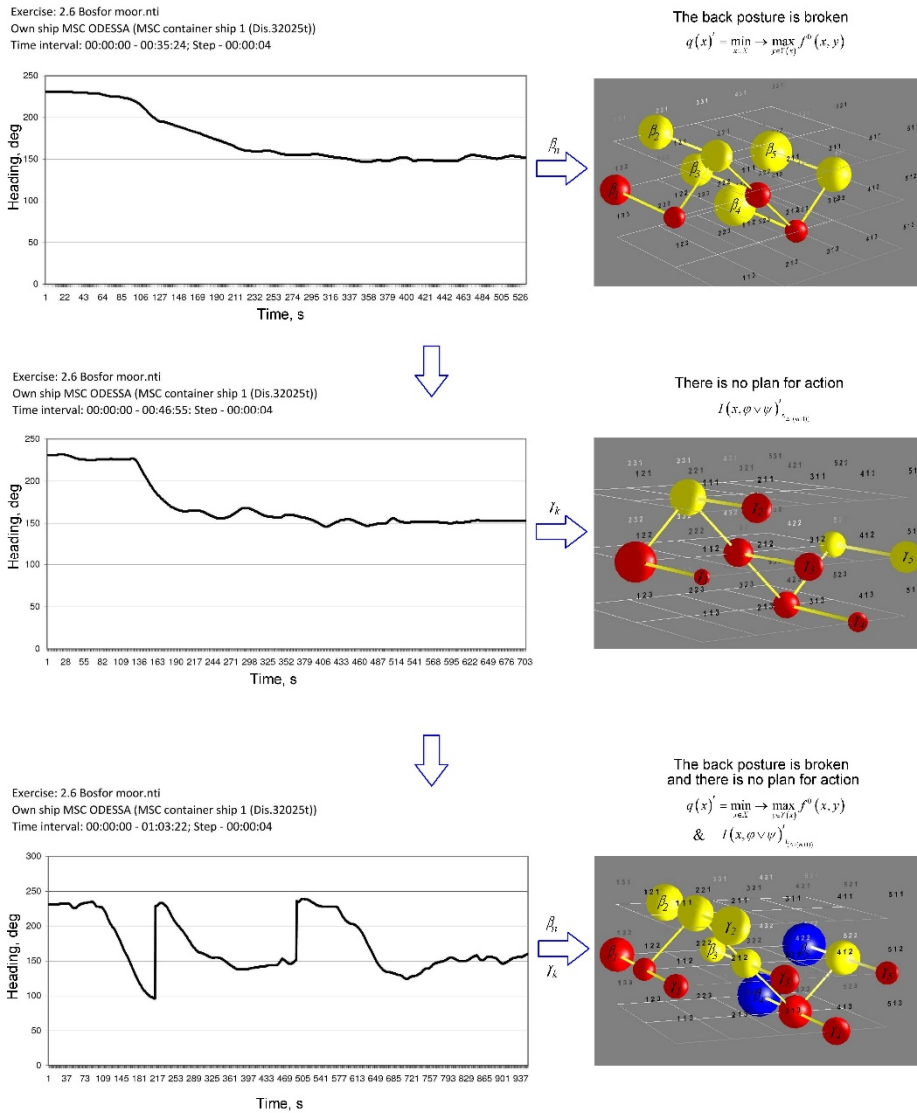


Fig. 10. Experimental confirmation of the hypothesis

3. The final obtained trajectories of the navigator's behavior at the time of critical situations were analyzed. There was obviously a need of using modal logic,

arranging the possibility to distinguish the classes of temporal fragments of the trajectories. Besides, the factors affecting the performance of individual elements of the trajectory appeared to be determined. This fact allowed us to identify the behavior strategies of navigators on the captain's bridge. All this data is sure to provide the opportunity to describe the effect of individual navigator behavior strategies on the final result.

The obtained results give valuable grounds for quality retraining of navigators in cases of negative manifestations of behavior patterns and strategy shaping of action plans in the form of a spatial transition or maneuver.

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Choice of Ship Management Strategy Based on Wind Wave Forecasting

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Abstract. The foundation of scientific research is being laid during the learning of navigator in higher school. As in any technical institution, in Kherson State Maritime Academy such basic disciplines as Higher Mathematics, Physics, and Information Technologies are taught from the first year of study. Curricula based on a competent approach to marine specialist training provides not only mastering the one or the other discipline, but also able to use the obtained knowledge in the professional activity. This article focuses on such an important question as a choice of ship management strategy based on the natural phenomena forecasting conducted on the results of statistical observations on environment behaviour, which surrounds a ship. Since task solution of analysis and forecasting is related with the usage of mathematical apparatus, study this theme within of the discipline “Information Technologies”, using possibilities of electronic tables, is supported by mathematical methods of construction of regression equations, solution of algebraic equations systems and in more difficult cases – solution of differential equations systems in partial derivatives. The modern development of information technologies and the power of software allow filling the educational material of disciplines with applied, professionally-oriented tasks. The using of mathematical modelling apparatus allows students to be able to solve such tasks.

Keywords: Forecasting, Natural phenomena, Wind wave, Mathematical model, Regression equation.

1 The general problem statement and its actuality

Systematic study of researching results of water resources behaviour, weather conditions, natural phenomena recorded in the form of statistic data contributed to the development of the methodological basis of analysis and forecasting processes which affect to the strategy of ships various purpose using in the all human activities. The analysis of researching results often makes possible to conclude about cyclicity of phenomena. It allows forecasting the climatic peculiarities of the region at one or another time interval. It ensures the safest ship’s movement tactics.

The information about dangerous and especially dangerous phenomena that can harm or break the terms of the voyage has a special value for the ship and its crew. The

largest number of studies is taking place in busy navigation and fishery. The distribution maps of water temperature and wave height on the seas and oceans are built by received information, and meteorological characteristics, compiled on these data.

Forecasting of natural phenomena that have different, both positive and negative influence on the strategy of ships using is the integral part of the scientific approach to management decision. Decision making by the chosen criterion is particularly relevant in the extreme working conditions at the sea. Sometimes ship's fate, health and lives of the crew depend on that decision. The foundation of forecasting is the base of the main features of studied phenomenon formed accordingly the analytical support of the future mathematical model.

The current stage of development of marine forecasts is characterized by using traditional and new methods of forecasting. Besides, modern computer technologies are widely used in the development of forecasting methods and in making operational marine forecasts.

In Kherson State Marine Academy (KSMA) the first year students study the discipline "Information Technologies". Its curriculum has several chapters "Work in Spreadsheets", "Conducting of calculations for navigators", "Solving of optimization tasks using MS Excel", "Data analysis and forecasting". The purpose of studying of the course material is not mastering the amount of knowledge in subject field activity but to form skills, abilities and competences which will provide the ability to analyze information and predict the behavior of the system for the next period, and to find the necessary ways to solve problems related to the performance of social and professional functions. The applied orientation of the discipline allows qualitatively forming subject competences connected with the using of data processing methods, calculation methods, mathematic and information modelling, business graphics.

This article focuses on the one of discipline chapter "Data analysis and forecasting" on the example of mathematical modelling of the phenomena forecasting connected with professional marine activity based on results of statistical observations of the water environment behaviour.

2 Analysis of recent research and publications, which launched the solution to this problem

Vasilii V. Shuleikin [25] has been greatly contributed to the tropical storms, ice, and wind wave researches. His works are in fact the theoretical basis of methods for predicting water temperature and have received the further development in modern researches of the features and regularities of the water environment. The study [2] is concentrated on analysis and methods of solving operational oceanographic service tasks. It covers such areas as hydrologic prediction (heat and water balance, ocean-atmosphere interaction), windswell forecasts, sea current and level forecasts, and ice prediction. The automated calculation system of optimal navigation course is built based on short- and long-term forecasts.

The works of Igor V. Lavrenov [14], Evgenii S. Nesterov [19], Leonid I. Piterburg [21] are dedicated to mathematical modelling of wind swell in the spatially and non-

homogeneous ocean. Aleksandr P. Khain [10] paid much attention to mathematical modelling of tropical cyclones. The manual "Marine Forecasting" [3] focuses directly on the methodological, statistical, mathematical fundamentals of the forecasting and reliability assessment, where detailed information on the gathering methods and analysis of data on the state of the sea and the oceans is offered, physicomathematical models of the short-term, long-term and over long-term forecasts of the main elements of the marine regime are considered. For example, the wind swell forecast provides practical advice on how to navigate the ocean.

Foreign researchers have also made a great contribution to analysis and forecasting of processes that affect to safe navigation (K. D. Pfeiffer [20], John Andrew Ewing [7] and others).

Fundamentals of numerical methods for solving problems are published in scientific and educational publications by Liudmyla I. Bilousova [4], Steven C. Chapra [5], Joe D. Hoffman [9], Illia O. Teplytskyi [23], Serhiy O. Semerikov [24]. Modern applications of numerical methods are associated with the use of information technology, so many scientists consider the MS Excel spreadsheet as a computer environment for modeling, such as Mohamed A. El-Gebeily [6] and Leonid O. Flehantov [8].

Problems of introduction of computer modelling in the study of informatics disciplines paid attention to Hennadiy M. Kravtsov [11], Lyudmila M. Kravtsova [27], Maiia V. Marienko [16], Oksana M. Markova [15], Yevhenii O. Modlo [18], Pavlo P. Nechypurenko [17], Yaroslava B. Samchynska [22], Mariya P. Shyshkina [26], Tatyana V. Zaytseva [27].

Modern operative oceanography develops by integration of many countries' efforts. International projects involving Germany, Italy, Portugal and the Netherlands are being successfully implemented. Understanding of importance direction in the study of World Ocean allows developing research effort that an improvement ship coordination and disaster prevention systems to ensure safe navigation are resulting.

3 Solving basic problems

Hydro-meteorological stations are the main source of statistical data. Their information is data about the past, present and future state of the seas and oceans, based on observations and appropriate methods of analysis and forecasting of oceanographic characteristics. Increasing of incoming information from all of its sources requires the introduction of new methods for the collection, transmission, processing and storage of hydro meteorological information. The use of modern computer technologies makes it possible to automate the process. It is clear, research work which is being done in this direction and its application are needed.

Unnatural hydro-meteorological conditions are particularly dangerous and scientific interested. Hydro-meteorological processes that, in terms of time, intensity, duration and area of occurrence, can cause significant damage or natural disasters relate to hydrologic extremes. There are dangerous and especially dangerous hydrological phenomena [13] on the seas and oceans, such as:

1. Irregular sea level variations (above or below critical points) in which populated places and coastal installations are flooded, ships and other household objects are damaged, and navigation is stopped.
2. Tsunamis that cause a sea level rise of 2 m or more.
3. Wave height is 8 m or more in the oceans; and wave height in the sea that are dangerous for navigation, fishing and coastal installations.
4. Tropical storms and typhoons when wind speed is 35 m/s and more.
5. The appearance of the ice cover at an unusually early date; is repeated no more than once every 10 years.
6. The pressure drift of floating ice that threatens oil rigs, flyovers and other facilities.
7. Ship icing when rate of ice growth is 0.7 cm/h or more.
8. Strong rip tide in the port waters.

Danger warning of port services, port-side territories, ships in the waters, maritime industries and population are faced by and caused by adverse hydrologic events is an important practical task. The initial materials for the warning are:

1. Forecast of an expected hydrologic hazard and the time of its occurrence.
2. Hydrologic hazard criteria.

Forecasting Methodological Bases. Hydro-meteorological condition forecasting provides for a scientific evidence system, development of different hypotheses and using methods that characterized by mathematical formalization [9]. The variability of oceanological processes depends on a rangier of factors, so marine forecasts tend to have a probabilistic nature. The long-term prediction of any characteristics of the seas and oceans regime can only be made approximately because all influencing factors to this process are unknown. Next, the forecasting methods as usually are based on the using discrete values of characteristics which also brings a certain error in the study results of this process.

Applying of cyclicity that discovered on a long series observations of forecasted characteristic is useful in a long-range marine prediction techniques besides physical patterns. Some methods of over long term forecasts take into account the influence of space and global geophysical factors (solar activity, long tides, fluctuations in the Earth's rotation axis, etc.).

Usage of the linearized system of hydrodynamic equations and simultaneously a non-linear model development is the methodological basis for the work on numerous long-term forecasts. Applying of statistical characteristics to solve the hydrothermodynamics equations is quite possibly. Space-time correlation relations between phenomena are established with the help of statistical methods. The advantage of using this approach to the forecasting problem is that own correlation matrix functions a priori contain useful information about the structure of some or other hydro-meteorological fields.

Methods of probability theory, mathematical statistics, factor and spectral analysis, differential equations describing physical processes whose characteristics form the basis of research are most commonly used as the mathematical apparatus in marine hydrologic prediction.

So, two main directions are considered in the development of marine forecasting techniques: physicostatistical and hydrodynamic. Using of the physical hypothesis that reveals the interrelations between predictors (factor feature or prediction parameters) and predictant (the resultant factor, or value that at the some point in time is determined using predictors) underlies physicostatistical direction. The physical hypothesis facilitates the task of applying statistical methods in forecasting.

Statistical methods for forecasting are provided an opportunity to evaluate the development of hydro-meteorological processes in the future based on the results of past observations using knowledge of probability characteristics of these processes. An observation series of the predicted characteristic and factors that it depends on is composed to establish a link between investigated quantities. Methodology development suitable for making operational forecasts is a complex scientific study that can be broken into several stages.

At the first stage of study a general patterns between phenomena are identified and main factors are determined. As forecasting experience has shown, many predictors that are used in the methods do not improve forecast quality. The optimal number of predictors is three or four as a rule. The optimal number of predictors is three or four as a rule. The optimal number of predictors understands a set of predictors when further increase their number does not lead to an increase of the correlation coefficient and improving forecasting results. The right decision when choosing the number of predictors is greatly facilitated development of forecast method and ensures the increased reliability of operational forecasts.

In the second phase of forecast methodology development, a general physical regularity that was previously identified applies to specific physical and geographical sea conditions. For this purpose, observational data that needed to develop of the method are carefully analysed for representativeness and comparability of observations in different years. Methods of operative forecast are usually local because World Ocean basins are very different on physico-geographical and ocean conditions. Attempts of researchers to create a common forecasting methods that would be suitable for large areas of the seas and oceans have not yet led to positive results, because of global differences in the basic characteristics of these objects.

A third stage is start of receiving predictive quantitative dependencies. Graphical comparison of predicted element with predictors should be considerate as a visual way to find connections. This technique gives possible not only to establish the existence of a statistical relationship, but also to determine the type of its dependency. A detailed analysis of the deviations should be made, and determine the reasons that led to a disturbance in the general regularity. The wider points' variation on the link's graph, the more influence degree of random factors.

Development of forecasting method of the oceanological phenomena, such as: wind-wave, marine currents, fluctuations, water temperature, etc., usually begins from with analysing and generalizing ideas about the general physical regularity of predicted phenomena, searching for factors that affect its changes in time and area, and identify among them the most informative in the prognostic sense. Other words, a researcher accepts the general provisions (hypothesis) based on the examination of priory

information about these phenomena that characterize relation, which must be found between the predicted phenomenon (predictive) and factors that cause it (predictors).

The next stage is the choice of the most adequate mathematical apparatus, which would allow the best approach to the problem, that is, the creation of a reliable forecast method.

Then, hydrodynamic methods of the forecast are based on solving of hydro- and thermodynamics equations. As of today, with some simplifications, numerical analysis for short-term forecasts of storm surges, water temperatures of the upper quasi-homogeneous ocean layer and its thickness, ice formation period, ice thickness increasing and melting of snow and ice cover have developed. For example, when ocean physical processes are described for Southern Hemisphere, such equations of thermodynamics of turbulent liquid can be accepted:

for moving:

$$\frac{du}{d\tau} = -\frac{1}{\rho} \frac{\partial p}{\partial x} + fv + \frac{\partial}{\partial z} k' \frac{\partial u}{\partial z} \quad (1)$$

$$\frac{dv}{d\tau} = -\frac{1}{\rho} \frac{\partial p}{\partial y} - fu + \frac{\partial}{\partial z} k' \frac{\partial v}{\partial z} \quad (2)$$

$$\frac{\partial p}{\partial z} = g\rho \quad (3)$$

for continuity:

$$\text{div}_h u + \frac{\partial \omega}{\partial z} = 0 \quad (4)$$

for heat distribution:

$$\frac{\partial t_\omega}{\partial \tau} + u \cdot \text{grad}_h t_\omega + \omega \frac{\partial t_\omega}{\partial z} = \frac{\partial}{\partial z} k_{t_\omega} \frac{\partial t_\omega}{\partial z} + \sum Q \quad (5)$$

for salt distribution:

$$\frac{\partial S}{\partial \tau} + u \cdot \text{grad}_h S + \omega \frac{\partial S}{\partial z} = \frac{\partial}{\partial z} k_s \frac{\partial S}{\partial z} \quad (6)$$

for state of sea water:

$$\rho = \rho(t_\omega, S, P_\omega) \quad (7)$$

where all parameters of the relation represent some characteristics of sea water condition.

This example illustrates, how complex the mathematical model of the phenomenon studied can be. The solution of hydrodynamic equations without professional mathematical training is practically impossible.

Students of Kherson State Maritime Academy learn discipline Information Technologies in the first year. It is clear that the first-year student hasn't sufficient mathematical knowledge to comprehend the essence of such equations. However, understanding of the importance of the data analysis and prediction, the main methods for their solving, possibility using in the professional navigational workload – quite an achievable task. Weak students' knowledge in the field of mathematics is a one of the problems that first-year students face from one side and teachers, which work with them from the other side. Therefore, the task before teacher is to systematize them knowledge, increase level of understanding mathematical formulas, recognizing them not as just "picture", but as an instruction for action that result is strategy to ship and crew management. And thanks to the applied aspect of mathematical models, student interest to natural-science disciplines can be increased.

Most simple way to objectively realization of information that's based on statistical observations for forecast of ocean phenomena is constructing a regression equation. Application of the mathematical statistics apparatus provides availability of long enough series of observations for predicant and predictors. These temporary series can be considered as system of random correlated variables. The normalized correlation matrix is a good feature of relations in such systems.

Functional dependence is a most studied kind of link between quantities, in term of implementation, when each value of one quantity (factor sign) X corresponds to quiet defined value (result sign) Y . But in practice, as a rule, have not dealt with functional dependencies, but of statistical ones. In this case, for each value of one quantity corresponds many possible values of another. Dispersing of possible values explains by the influence of many additional factors, which usually neglected when relations between quantities are studied. A dimensionless correlation coefficient characterizes the measure of linear dependence between variables, that in absolute value no more than one: $abs(r) \leq 1$.

Correlation coefficient equals zero for independence quantities X and Y . Equality of the correlation coefficient to zero means that linear dependence is absent (but does not eliminate nonlinear dependence). Another correlation methods are used in nonlinear relationship. The closer the absolute value of correlation coefficient is to one, the closer the linear dependence between quantities. Equality of correlation coefficient to one means that functional dependence is present between X and Y . Correlation coefficients don't change when starting point and measurement scale of quantities of X and Y are changed. It makes possible for significantly simplify the calculation by selecting a convenient starting point (X_0, Y_0) and corresponding units of scale. The correlation coefficient and regression equation for both variables can be found approximately from the correlation chart, and more accurately – by method of least squares.

First-year students, at the time of studying the topic "Data Analysis and Forecasting. Linear and quadratic regressions" have fully mastered the basic techniques of MS Excel spreadsheets, have skills (in accordance with a course syllabus) to solve systems of linear equations using the Cramer method and matrix method, calculating the inverse matrix and matrix multiplication operations using built-in functions. In terms of obtaining parameters of the linear and quadratic dependences in accordance to the method of least squares for building of an optimal analytical function, that's enough, if

student's understanding of the problem formulation, its solving methods and analysis of the obtained results. Appropriate theoretical material and stepwise solution of the classical task of the task of finding dependency parameters of linear and quadratic regression for students are posted on the discipline "Information technologies" webpage of the E-learning system KSMA (based on the Moodle).

Our objective is to show student, the future navigator, how important to have the analysis skills of real situation based on observations, to forecast, to apply their knowledge in practice, to make the right management decision. For this purpose, real application tasks are proposed to the student after the techniques of solving the classical task of linear and quadratic dependence equations constructing founded by the table data (results of observation) he has mastered.

Consider a typical task of wave height forecasting depending on wind speed and the duration of its effects (forecasts of wind waves).

As a result of the enhancement of sea economic activity, the knowledge of its condition and forecast changes is of great practical importance [9]. Accordingly, the role of the wind swell forecast significantly increases.

Using of information about actual and expected conditions of wave swell helps to successfully navigate the most profitable routes, water landing, offshore drilling, effective and safe fishing, sea loading, sporting regattas, etc.

Characteristics of the maximum waves are most important characteristic of sea swell, because these waves are the most dangerous for ships and hydrotechnical structures. Therefore, the efficiency of the swell forecast depends largely on how well predict characteristics of the maximum wave. Note that, the term "forecast" for wind swell is used conventionally to difference retrospective calculations from the daily operational calculations of the meteorological predictions of the wind field.

The main elements of wind waves are: height H , period T , length X , phase speed C , steepness E ridge length L .

In case sea depth is more than half the wavelength, wave elements are independent of the depth. If sea depth is less than half the wavelength, then wave elements are change influenced by seabed. The concept of "deep water" has a relative meaning and is defined by the ratio of depth H and wave length X .

Table 1 data are the basis material of parameters for analysis and making forecast.

Table 1. Wave height depending on wind time

Wind speed	Wind duration (in hours)						
	5	10	15	20	30	40	50
10 knots	2.0	2.0	2.0	2.0	2.0	2.0	2.0
15 knots	3.5	4.0	4.5	5.0	5.0	5.0	5.0
20 knots	5.0	7.0	8.0	8.0	8.5	9.0	9.0
30 knots	9.0	13.5	15.5	17.0	18.0	18.5	19.0
40 knots	13.5	21.0	25.0	27.5	31.0	32.0	33.0
50 knots	18.0	29.0	36.0	40.0	46.0	48.0	50.0
60 knots	23.0	37.0	46.0	43.0	61.0	66.0	70.0

The task is to determine the type and dependence parameters of the wave height on the wind duration. Based on the table data where row number corresponds to the column of wind duration that is measured in hours, the charts are drawn (see Fig. 1).

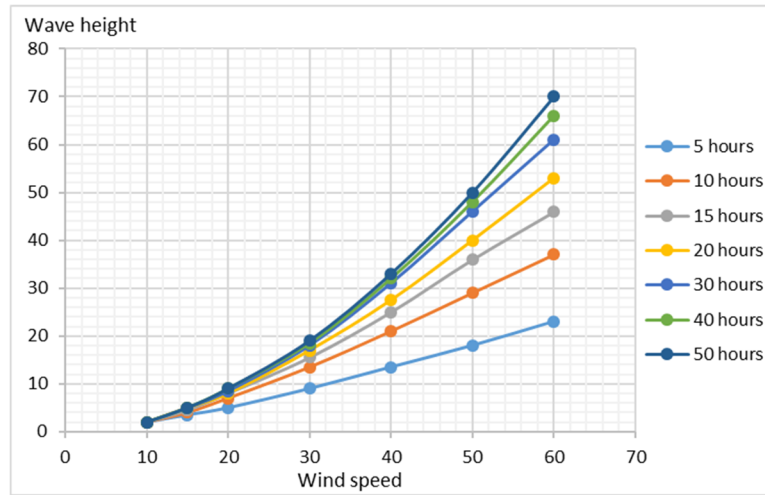


Fig. 1. Dependence of wave height on wind speed and duration

The created scatter chart allows making conclusion that in the wind duration from 5 to 15 hours the dependence can be approximated by linear function; in the wind duration from 20 to 50 hours the dependence will be probably quadratic.

Let us find the dependence parameters which are relevant and evaluate average squared deviation for each of obtained analytic relationships.

Three ways are offered to student for finding the parameters of linear dependency that are determined by the solution of the equations' system (8).

$$\begin{cases} a_0 \sum_{i=1}^n x_i^2 + a_1 \sum_{i=1}^n x_i = \sum_{i=1}^n x_i y_i \\ a_0 \sum_{i=1}^n x_i + a_1 \cdot n = \sum_{i=1}^n y_i \end{cases} \quad (8)$$

1. Using Cramer's formulas.

$$a_0 = \frac{n \cdot \sum_{i=1}^n x_i y_i - \sum_{i=1}^n y_i \sum_{i=1}^n x_i}{n \cdot \sum_{i=1}^n x_i^2 - \sum_{i=1}^n x_i \sum_{i=1}^n x_i} \quad (9)$$

$$a_1 = \frac{\sum_{i=1}^n x_i^2 \cdot \sum_{i=1}^n y_i - \sum_{i=1}^n x_i \sum_{i=1}^n x_i y_i}{n \cdot \sum_{i=1}^n x_i^2 - \sum_{i=1}^n x_i \sum_{i=1}^n x_i} \quad (10)$$

2. Using Excel's built-in functions SLOPE (parameter a_0) and INTERCEPT (parameter a_1).
3. Using Excel's Solver add-in "Trendline. Linear".
4. The objective of such approach is that student has to, firstly, understand analytic formula, action order, can be possible to calculate by formula; secondly, to use built-in functions and thirdly, to use add-ins.

Performing the calculations show that the results obtained by three different methods match and confirm the hypothesis about linearity of dependences, because the regression coefficients, that are corresponding, R^2 (approximation reliability) are close to 1 (the type of dependence is chosen correctly):

first row (wind duration 5 hours):

$$y = 0,423x - 3,004; R^2 = 0,995 \quad (11)$$

second row (wind duration 10 hours):

$$y = 0,71x - 6,62; R^2 = 0,9946 \quad (12)$$

third row (wind duration 15 hours):

$$y = 0,893x - 9,132; R^2 = 0,9909 \quad (13)$$

Parameters of quadratic dependence $\bar{y} = a_0x^2 + a_1x + a_2$ are determined by system decisions:

$$\begin{cases} a_0 \sum_{i=1}^n x_i^4 + a_1 \sum_{i=1}^n x_i^3 + a_2 \sum_{i=1}^n x_i^2 = \sum_{i=1}^n x_i^2 y_i \\ a_0 \sum_{i=1}^n x_i^3 + a_1 \sum_{i=1}^n x_i^2 + a_2 \sum_{i=1}^n x_i = \sum_{i=1}^n x_i y_i \\ a_0 \sum_{i=1}^n x_i^2 + a_1 \sum_{i=1}^n x_i + a_2 \cdot n = \sum_{i=1}^n y_i \end{cases} \quad (14)$$

and are found by matrix method using built-in mathematical functions.

We will remind that system can be presented in matrix form $A\bar{x} = \bar{b}$, where A is the coefficient matrix, \bar{x} is the unknown vector column, \bar{b} is the right part. If A^{-1} is the inverse matrix, then solution of the system has a view $\bar{x} = A^{-1} \cdot \bar{b}$. In our case the parameters of quadratic dependence a_0, a_1, a_2 will be system solution (built-in functions MINVERSE and MMULT are used). Accordantly,

fourth row (wind duration 20 hours):

$$y = 0,0115x^2 + 0,2714x - 1,7868; R^2 = 0,9998 \quad (15)$$

fifth row (wind duration 30 hours):

$$y = 0,0115x^2 + 0,3945x - 3,5319; R^2 = 0,9992 \quad (16)$$

sixth row (wind duration 40 hours):

$$y = 0,0144x^2 + 0,2763x - 2,3435; R^2 = 0,9999 \quad (17)$$

seventh row (wind duration 50 hours):

$$y = 0,0166x^2 + 0,2013x - 1,7246; R^2 = 1 \quad (18)$$

Applying the obtained equations (analytical dependencies), it is possible to make a wave height forecast for any wind duration and actually any wind speed.

An expert review of the proposed material was conducted to support expedience of teaching “Data analysis and forecasting” of the course “Information Technologies” on example of math modelling of wave height forecasting in depended on some nature factors and also of the adequacy of the built model to the real conditions. For it, the Method of Expert Estimations (or Delphi method) has been used. This method is the following: expert group was requested to review the work, evaluate its professional direction, reply to the questionnaire and draw conclusions about actuality of the proposed study and the practical application of the obtained results.

The method is used for obtaining quantitative assessment of quality characteristics, parameters and features. Analysis of expert estimations involves each expert completing an appropriate questionnaire, which will help to obtain an objective analysis of the problem and to develop possible solutions [12].

A group involved to work was consisted of marine industry specialists, chief officers and sea captains who works at the academy or undergoes retraining and has extensive experience on the ships. The twelve persons were invited for expert evaluation in a total. The authors took into account such factors as competence, constructive thinking, attitude to work as an expert when form expert group.

The purpose of expert estimation is an establishing of efficiency index (quality) compliance of the proposed method of authenticity solving the real situation.

To confirm or contradict the research conclusions, we used the following forms of conducting and processing expert evaluations:

1. Determining experts' competence and forming of expert commission composition.
2. Construction of the quality weighting coefficients ranking.
3. Parameterization of quality indicators.
4. Conducting expert quality assessment.

Study of the adequacy of obtained examination results.

Expertise of computer modelling method efficiency when analysing natural phenomena should take into account cognitive, software and technological, psychological and pedagogical features.

The expert questionnaire consisted of 16 questions, 12 experts took part in the survey. A quality indicator is number parameter which determines evaluation of the

method according to its qualitative characteristics, 5-Point Likert Scale [1] was used for this.

For example, there is a table 2, which contains several questions.

Table 2. (Questionnaire fragment) Quality parameters and their weighting coefficients

No	Name of quality	Qualitative parameters	Weighting coefficient
1	Compliance with the STCW Convention, IMO Model Courses, requirements of the Shipping Register of Ukraine	Full Lack of full No	5 3 1
2	Completeness of the proposed method for solving the problem	Full Lack of full Average Below average Low	5 4 3 2 1
3	Feasibility of using mathematical modelling methods in teaching IT discipline	Full Lack of full Average Below average Low	5 4 3 2 1
4	Feasibility of using methods of mathematical modelling of wave height forecasting depending on certain natural factors	High Average Low	5 3 1
5	Adequacy of built model to the real process	Yes Partly No	5 3 0
6	Efficiency of computer-assisted processing of observation results	Quality Above average Average Below average Low-quality	5 4 3 2 1

The expert evaluation of method efficiency will only be reliable if expert responses are agreed, and concordance method will be used for this purpose.

When measuring the ordinal scale by the ranking method, the purpose of processing the individual expert assessments is construction of generalized objects' order based on the averaging their assessments.

Using questionnaire data the summary rank matrix has been compiled (Table 3).

Table 3. Types of criteria

Expert	Types of criteria															
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1	3	8	13	4	7	2	6	9	5	12	10	11	16	14	15	1
2	4	10	11	6	8	2	3	5	7	12	9	13	14	15	16	1
3	3	10	12	7	8	2	6	4	5	11	9	13	14	15	16	1
4	4	7	10	6	8	2	5	3	9	12	11	14	13	15	16	1
5	2	10	14	9	8	3	12	4	5	6	7	11	13	15	16	1

Expert	Types of criteria															
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
6	3	9	10	8	7	2	6	4	5	11	12	14	15	13	16	1
7	2	12	11	8	10	5	4	3	7	13	6	9	14	15	16	1
8	2	11	14	7	9	4	5	3	6	12	8	10	13	15	16	1
9	2	11	14	4	8	9	10	5	6	16	3	7	12	13	15	1
10	2	5	13	8	7	3	6	4	10	11	9	12	16	14	15	1
11	2	11	12	6	10	5	4	3	8	13	7	9	14	15	16	1
12	2	9	11	7	8	3	4	5	6	10	12	13	14	15	16	1
Δ_i	-71	11	43	-22	-4	-60	-31	-50	-23	37	1	34	66	72	87	-90
S_i	5041	121	1849	484	16	3600	961	2500	529	1369	1	1156	4356	5184	7569	8100

Let us calculate the concordance coefficient by formula:

$$W = \frac{12S}{m^2(n^3 - n)} \quad (19)$$

Computed by the formula (19) coefficient $W = 0,875$ is closer to one (concordance coefficient can vary from 0 to 1), so we can consider that the experts' answers are agreed.

Let us calculate the Pearson matching criterion to evaluate the significance of concordance coefficient:

$$\chi_W^2 = \frac{12S}{m \cdot n \cdot (n+1)} = 157,49 \quad (20)$$

Calculated criterion χ^2 is comparable to the table value for number of degrees of freedom $K = n - 1 = 16 - 1 = 15$ and at the specified significance level $\alpha = 0,05$.

Conclusions of expert commission. Since χ^2 calculated is 157,49 that is greater than or equal to critical (24,99579), so $W = 0,875$ is non-random value, therefore the experts' conclusions confirm the practical significance of the results obtained in the article and practicability of their use for further research.

4 Conclusions and directions for further research

A professional navigator, a specialist with advanced training, who claims an officer's position on a ship, has to know not only all the details of navigation and sailing directions, ship's construction, has skills to work with crew and so on. The navigator is responsible for safety of navigation, safety of the ship, crew and cargo. So, he has to follow the instructions of the coastguard controlling the ship's movement, but to analyze the current situation and forecast the consequences of his decisions.

The aim of the discipline "Information Technologies" is studying of the mathematical (computer) modelling method, its application in various subject areas, as well as ability to predict and analyse the results of obtained decisions. In other words,

the discipline lays one more necessary brick in the formation of competencies set of a marine industry specialist.

The learning material of discipline provides that students solve problems formulated in their subject area and related to formalization and further use of computer technologies. Such tasks require considerable time for solving, system approach to development.

In the using of information technologies, students practice skills of development of information models, solution algorithms, evaluating of obtained results. They feel a qualitatively new socially significant level of competence; develop professional qualities of a person.

Significant number of navigational, engineering tasks is reduced to the solving of the equations (inequations), the system of equations (system inequations), differential equations or systems, calculating the integrals described objects or phenomena. Using of mathematical (information) modelling methods, forecasting of decision-making results in various activities demand specialists to mastery of the appropriate mathematical apparatus.

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The Procedures of Logistic Transport Systems Simulation in the Petri Nets Environment

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Abstract. The article presents the methodology of the logistic system simulation into the Petri Nets environment on the example of agro-products delivery from Ukraine to the Netherlands, as well as a set of case-studies that can be used as didactic means for course “The modeling of transport processes” to teach the future transport industry specialists. The content, features and capabilities of the Petri Nets in the logistics systems simulation have been analyzed. A structural logistic system model of agro-products delivery, which takes into account the operation sequence, the combination peculiarities and the use resources in each subsystem, has been constructed into the Petri Nets. A time criterion has been proposed to determine the effective option for agro-products delivery. According to the results of the logistics system simulation into the Petri Nets environment, a statistical analysis of the parameters has been carried out. It has been made a choice of a suitable option of the delivery scheme allowing for the time spent and the magnitude of the possible costs associated with the use of certain transport modes. It has been made conclusion about feasibility of creating the case-study set, which is based on real facts and being solved into the Petri Nets environment, in order to organize the future transport industry specialists’ study and research activities.

Keywords: simulation, logistic system of cargo delivery, Petri Nets, vocational training of future specialists for transport industry.

1 Introduction

Today, in fact, Ukraine is one of the world’s leading exporters of agricultural products. The agro-industrial complex is the most priority sector of the Ukrainian economy. In the near future the strategy of its entry into the European Union market is essential for the development of Ukraine. In line with this viewpoint, along with the economic and technical aspects, it becomes significant content and directions of the transport industry specialists’ vocational training. Such specialists should know the general patterns of logistic systems development, the features and trends of management and material

flows optimization; they need orient and apply modern computer-based methods of logistic systems simulation.

We would like to show the most indicative data describing the facts of increasing the volume of agricultural products transportation. In the period January-September 2019, agricultural products were exported to the EU at 4.76 billion USD, which is 106.9% more than in the previous year, and it constitutes 30% of Ukraine's total exports [20]. According to *IMF group Ukraine* estimates, the total potential agricultural demand for rail transportation by 2022 may increase from 52.4 (2018) to 70 or 95 million tons of annual freight. For its part, a rise in grain production causes a corresponding growth in the consumption of chemical and mineral fertilizers. By 2022, this figure can increase by 22.8% [29].

By results of 2019, the seaports of Ukraine had raised the volume of cargo transshipment by 18.4% and reached record high performances in the whole history of their existence. For the first time, the volume of transshipment of 13 Ukrainian active ports exceeded 160 million tons [10]. The maximum indicators of transshipment of grain cargoes and ore were recorded. Container transportation overcame a 10-year high of 1 million TEU. In total for 2019 the Ukrainian seaports handled 11,850 vessels, which as likely 196 ones (1.7%) as last year. Grain loads and oil accounted for more than a third (37.7%) of the total cargo flow. Four ports of Ukraine became the leaders in terms of transshipment in 2019. They were the Port Yuzhny – 53.9 million tons (+ 26.1% to the last year), Mykolayiv – 33,4 million tons (+ 14.5%), Chernomorsk – 26.2 million tons (+ 21.4%), and Odessa – 25.3 million tons (+ 16.8%).

Along with the increasing volume of transportation, there are difficulties associated with the efficient management and construction of a supply logistics “rigid schedule” from the production location to the consumer. These difficulties are due to the fact that the logistic system of agricultural products delivery has many links, including informative ones, and involves a large number of elements [33]. Yet another problem is the unjustified additional costs for the agricultural products delivery. In Ukraine grain freight, e.g., costs an additional 8 US\$ per ton compared to France and Germany. Transportation value includes the cost of pure transportation, ware-housing, storage, cleaning, drying of goods, handling operations, processing documents, packaging, security, as well as the payment of any commissions, tariffs and fees because of the grain export. On account to increased logistics costs, Ukrainian agricultural producers receive less profit in contrast to world market prices. They have to bear the costs caused by the inefficiency of the logistic system [31].

The active ICTs development in the previous years has allowed to accelerate the process of presentation, processing and use of information in the logistic system for the delivery of various cargo types [22]. But here too, there are troubles and problems in creating effective information systems in enterprises. One of the first things is deficit of prompt collection of reliable information in companies. Mostly companies suffer losses as a result of untimely or incorrect data on the operational situation at each stage of the logistics supply chain [5]. Therefore, today attention is increasingly drawn to the information flow through which the movement of material resources is planned, managed and controlled [34]. There is a need to model and study the behavior of the logistic transport system in order to obtain information and forecast its most important

characteristics. The systems of parallel processing information and parallel objects operating allow to solve the problem with effective interaction of individual elements of this delivery frame. The best of these are models based on the Petri Nets Theory.

In light of these facts, the implementation in the content of the future transport industry specialists vocational training the case-studies based on simulation into the Petri Nets environment will be able to prepare them for work in real conditions of the transport process organizing.

The purpose of the paper is to present the methodology of the logistic system simulation into the Petri Nets environment on the example of agro-products delivery, as well as a set of case-studies that can be used as didactic means for course “The modeling of transport processes” to teach the future transport industry specialists.

2 Materials and methods

Nowadays, freight delivery management in Ukraine during the execution of applications uses techniques based on heuristic methods; on own managerial experience and on degree of responsibility. In practice, this means the occurrence of real losses associated with the increase in the cargos delivery time, downtime of wagons at the approaches to ports, at border crossings and at warehouses of enterprises (elevators), as well as it caused by arrhythmia in the operation of transport subsystems in general. A selective analysis of the cargo delivery time, conducted by Hanna I. Kyrychenko, shows that the violation of the term occurs in transportation for all types of dispatch at 5%, container – 32%, rail wagon – 17% and group shipments – 8% [14]. Therefore, the logistics delivery system, e.g. of the agro-products, should cover the consideration of the transportation organizing both by motor-cars and railroad wagon, and with the use of containers [32].

It's generally recognized the effective supply tracking is critical to managing global trade and logistics [21]. To cope with the growing complexity of customer requirements, supply chain organization and management systems are constantly moving towards the area of collaboration, intellectuality, and service orientation. This fact has been emphasized by Riccardo Giusti, Daniele Manerba, Giorgio Brunoa and Roberto Tadei [7], Olexiy Pavlenko and Denis Kopytkov [16], Shenle Pan, Ray Y. Zhong and Ting Quc [21] and others. Majority logistic companies in the world have made cargo tracking a must in the delivery chain [15]. However, flow management is still a challenge for supply participants. This fact confirms the feasibility of the idea of a smart system for monitoring the promotion of cargos in containers in the multimodal transportations context [32]. A number of papers (Victor Aulin, Oleg Lyashuk, Olexiy Pavlenko, Denis Velykodnyi, Andrii Hrynkyv, Sergii Lysenko, Dmytro Holub, Yuriy Vovk, Volodymyr Dzyura, Mariana Sokol, Dmitriy Muzylyov, Natalya Shramenko, Vladyslav Shramenko) also reveal a complex multifactor system to track cargos movement on the grounds of computer-based simulation [2; 19; 26].

Undoubtedly the technology of transport systems computer simulation is a very sophisticated professional technology. It provides a system for information gathering with use of data collection card, which is too much costly and not always an effective

process. In so far years, thanks to widespread implementation of ICTs, the simulation technologies have been developing rapidly. Based on the model of activities of organization, researchers (Haya Hasan, Esra AlHadhrami, Alia AlDhaheeri, Khaled Salah, Raja Jayaraman) reveal the content, concepts and methodology of simulation technologies, methods of simulation modeling and simulation experiment, as well as typical algorithms for simulation of various processes. In [8] the authors also proved the relevance of simulation of events occurring in the pragmatist processes. General issues about computer-aided students' simulation training have been covered by Roman M. Horbatiuk, Olena O. Lavrentieva, Serhiy O. Semerikov, Vladimir N. Soloviev, Illia O. Teplytskyi and others [9; 17; 28].

It has been found that the most promising for describing the process of cargos delivered by transport technological schemes is the use of simulation modeling. Unfortunately, there are some complexities while designing and creating new models. They are caused not so much by number of projected system elements, but by the complication of causation in the complex of components which are interacting, interconnected and interdependent. To solve the problems of optimizing the functioning of logistic systems separately and as a whole, Yi-Min Deng, Aibing Yu, Weihua Li and Di Zheng [11], Natalya Shramenko, Dmitriy Muzylyov and Vladyslav Shramenko [27] developed the neural networks. At the same time, it is the Petri Nets that can be more effectively used to simulate the systems with parallel processing of information and objects.

The Petri Nets, as it has been pointed out by Wei Zhu Zhong, Xiao Qing Fu and Ya Ping Wang [36], Natalya Shramenko, Olexiy Pavlenko and Dmitriy Muzylyov [25], Guan Xiang Zhang, Shan He and Zhi Yong Zhang [35], Mouhaned Gaied, Anis M'halla, Dimitri Lefebvre, Kamel Ben Othmen [6] and others, are much more commonly exploited to investigate an object behavior in real time and to evaluate the performance of the transport system. The Petri Net Theory is a mathematical apparatus designed to work with parallel and asynchronous systems. It first described in 1962 by the German mathematician Carl Adam Petri. Now the theory is being considerable used virtually in every field of research [3]. In the following we consider the potential of the Petri Nets environment in transportation system simulation, as well as its benefits for organizing vocational training for future specialists for transport industry.

3 Theoretical background

First of all, to simulate the transportation system an object-oriented model should be constructed. This type of simulation is a simple and concise method of modeling and competent mathematical analysis for all spheres of activity, including logistic systems. An object-oriented model describes the structure of system objects, their attributes, operations, links with other objects [12]. Such simulation reflects those concepts and objects of the reality that are principal for the system development. It is object-oriented technology that is combined with Petri Nets for studying logistic processes [18].

The Petri Net is a clear and well-formalized simulator for the behavior of parallel systems with asynchronous interactions. It reflects in a compact form the links structure

between the system elements and dynamics of changing its states under given initial conditions [4]. The model abstraction level is very high. It corresponds to the description of interactions in the system in terms of only two concepts – events and conditions. The Petri Nets are integration of a graph and a discrete dynamic system. Thus, they can serve as a static and dynamic object model, which in turn makes it possible to solve a fairly wide class of tasks [4]. Petri Nets allow modeling the assembly lines, simulation and analysis of technological processes and resource allocation of the enterprise.

Graphically, the Petri Net is interpreted as a bipartite oriented graph with a given initial state, called the initial marking (or token) – M_o [4]. The graph consists of nodes (vertices) of two types – places (positions) P (i.e. conditions) and transitions T (i.e. events that may occur); they are connected by arcs. The same type nodes can't be tied together. The marking can be put within the position and may move by network. At the Petri Net diagram, positions are represented by circles, transitions – by bold bars, and arcs are signified by arrows. The directed arcs describe which places are pre- and/or postconditions for which transitions. The arcs are denoted by the weight factors (integers). It's accepted that the arcs with equal weights k are equivalent to parallel arcs. Marking (state) attributes to each position regard as an integer non-negative number $M(P)$ equal to the number of chips in position P [1]. So, a formal presentation Petri Net is following:

$$PN = (P, T, F, W, M_o), \quad (1)$$

where $P = (p_1, p_2, \dots, p_m)$ – is a finite set of positions; $T = (t_1, t_2, \dots, t_n)$ is the finite set of transitions; F – set of arcs (flow relationships)

$$F \subseteq (P \times T) \cup (T \times P), \quad (2)$$

where $W: F \rightarrow (1, 2, 3, \dots)$ is a weight function; $M_o: P \rightarrow (0, 1, 2, 3, \dots)$ is the initial marking.

In modeling tasks, where the concepts of conditions (states) and events are applied, positions comply conditions and transitions are events. Each transition (event) is associated with a certain number of input and output positions-analog according to the pre- and postconditions of this event. The presence of a chip in some position is interpreted as the truth of the condition corresponding to that position, and also indicates the availability in the position k of data elements or an appropriate amount of resources [1].

Models based on Petri Nets allow to analyze two types of properties defined by the original M_o marking and independent from it. The first-kind properties are called behavioral ones. Reach, limited, and energy are main for them. The second kind properties are called structural ones. They are characterized, as a rule, by the matrix of incidents C and related equations and inequalities. These include structural limitation and activity, safety, repeatability, and etc. The safety and repeatability properties enable to respectively determine the positional and transient invariants into the Petri Nets environment.

Known methods for analyzing the properties of Petri Nets are divided into three groups: 1) methods based on building multiple reach; 2) ones using matrix equations and network invariants; 3) ones allowing decomposition of the network to the subnet. The main areas of applied the Petri Net Theory are synthesis, analysis and modeling. The purpose of the Petri Nets simulation is to investigate the dynamics of studied system functioning and its behavior for different initial conditions. However, the popularity of Petri Nets is caused not only because of their high modeling possibility, but also thanks to a well-developed formal apparatus for analyzing the properties of a constructed model [24].

Next, we will consider the capability of the Petri Nets to solve the problems of logistic systems simulation. By way of example we will analyze the agricultural products delivery from Ukraine to the Netherlands. The choice of this country is caused by the fact that the largest volume of Ukrainian agricultural products export accounts for the Netherlands – 1.06 billion US\$. Furthermore, of the 16 commodity items of cargo shipment to this country, grain crops are of the highest importance; their part is 43.6% of the total volume of transportations [31]. To accomplish the construction task of efficient logistics system, it is necessary to develop a model of agro-products transportation from a manufacturer in Ukraine to a destination seaport in the Netherlands, to perform simulations to determine the estimation parameter – the time, as well as to clarify the conditions for the effective functioning of the entire delivery process.

4 Technique for using Petri Nets to simulate the logistic systems

4.1 General overview of the logistic system for agricultural products delivery from Ukraine to the Netherlands

In general, the logistic system of agricultural products delivery in Ukraine has a structure based on the interaction of such participants as: traders – organizers of products export, manufacturers, storage systems, transport companies, as well as the existing infrastructure of ports, railways and highways. The traders are a centralized system of the required technological level, aimed at organizing the interaction between participants, and besides, on receiving and analyzing input and output data, and to ensure greater transparency of the delivery process [30]. The logistic system can be interpreted as a holistic perspective, built in real time for all its participants allowing traders to make appropriate short-term and long-term decisions directed at the process development.

The system is built from the following subsystems: harvesting, transportation to the departure port, shipping by sea. The macro-level structural model reflects it in a comprehensive manner (see Fig. 1). To determine the effective delivery option, the main investigated parameter we defined the delivery time of agricultural products. Clearly, the time minimization process is affected by intensities of the receipt of orders and technical means – I_V , the volume of the order – Q_V , and time of execution of the

main operations in the corresponding subsystem – t_V . It means following:

$$T = \{I_V, Q_V, t_V\} \quad (3)$$

Each of the time minimization parameters consists of a number of components. Presumably, duration of technological operations and time of work technological intervals determine the variables that could be managed. The main system parameters change under the influence of load on the simulation model and during its management. These model parameters act as phase variables that can vary depending on the load on the system.

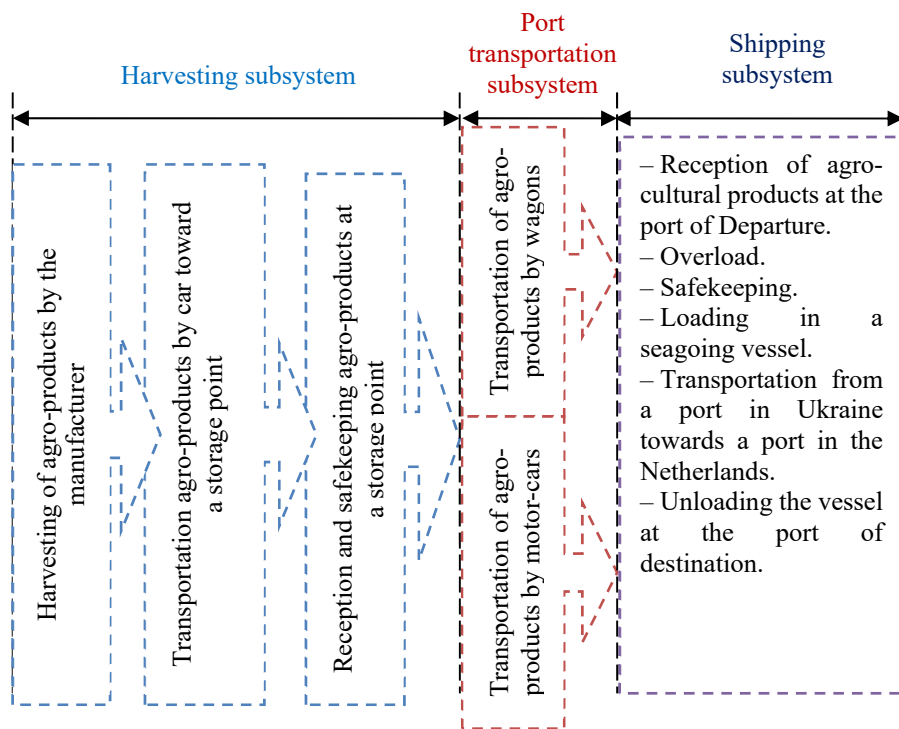


Fig. 1. The structural model of the agricultural products delivery system from Ukraine to the Netherlands

To construct a transport system model, it is advisable to employ a stochastic estimation of the Petri Nets, where the vertices of the places have an integer number of marks and are used to quantify some parameters of the system functioning like reliability and performance. In such networks each transition is attributed to a probability of its activation over time [24].

Considering the functional connections between the elements, it's possible to construct an enlarged model into the Petri Nets environment (Fig. 2). The model will

be to describe the logistics system functioning – the process of promotion of agro-products from the sender (Ukraine) to the destination seaport (the Netherlands).

The presented scheme depicts the process with the established elements. As for transitions, these determine following ones: T_1, T_2 – intensity of applications receipt from the trader and the farmer; T_3, T_5, T_3, T_{10} –time of cargo moving respectively by cars, wagons, sea vessels; $T_4, T_7, T_8, T_9, T_{11}$ – the corresponding distribution of cargo, information, technical means. The positions are represented by: P_1, P_2 – the presence of agro-products from the farmer and demands (technical means) from trader; P_1-P_{13} are cargo position at each operation stage.

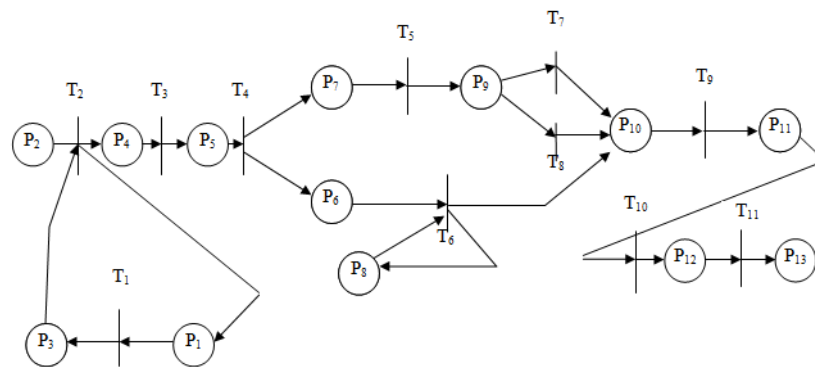


Fig. 2. The model of agro-products movement from the sender to the destination seaport

As can be seen, movements and positions are key points to the model presented. Therefore, in the future in modeling process, it should be paid maximum attention to these aspects.

4.2 General description of the Petri Nets application

As mentioned above the Petri Net modeling technique can be used for qualitative and quantitative analysis of workflow and workflow system in general. Apps market proposes a lot of offers that are founded on general modeling methodology into Petri Net environment [23].

Petri Net Integrated Simulator is aimed at the research and development of complex systems in various subject areas, including road transport. It provides following: 1) automation in construction of complex objects models; 2) simulation in step-by-step modes for tuning models, and statistics collection; 3) the formal analysis of systems represented by Petri Nets in terms of their structural and behavioral properties [23].

The Petri Nets graphic editor is aimed at creation and edition of Petri Nets and their modifications (F-networks, temporary networks, etc.) presented in graphical form. The editor is based on the general ideology of the multi-window interface and is functionally divided into two parts. The first part is the basic; it ensures the construction and edition of the Petri network overall structure. The second part is parametric; it provides the change of parameters of the network basic elements such as position (P) and transitions

(*T*). The parametric part, in turn, also consists of two parts where each one processes either “position” or “transitions”. The work of parametric part is ensured by changing the parameters of the network elements via directly interacting with the main objects of the general data structure like “position” and “transition”.

The simulation process consists of two main parts. First one is the window user interface (presented on Fig. 3) and second one is the Petri network operation procedure. The simulation process in part of window-user interface is founded on the widespread ideology of software complex organizing and uses the functions of the multi-window interface created within it. By virtue of this fact, the process interacts with external devices (and through them with the user) and messaging with other complex processes.

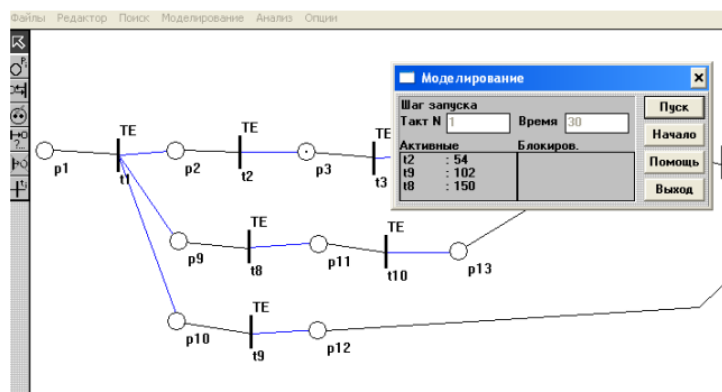


Fig. 3. Window fragment of the simulation process

The operation procedure applies for its work a special structure data created for storing, modifying and processing the Petri Net description. The operation procedure is started by the command of window-user interface and sequentially executes the simulation algorithm until it is interrupted by the user or by the command window according to the specified simulation mode. This mode sets in the Mode menu item.

An integrated system of modeling and formal analysis based on Petri Nets can be applied in the future transport industry specialists vocational training process. In particular, in order to create the content and educational tools of the course “The modeling of transport processes” and for students’ study and research work.

4.3 A case-studies set for the analysis and statistical evaluation of logistic models

In order to simulate the functioning of the logistic system of agro-products delivery, it is necessary to carry out a statistical analysis of parameters that are used to set initial values by transitions and positions in the Petri Net environment.

Case-study 1. You need, based on the data presented on the volume of cargo and the number of wagons for *Kernel Trade* – a large vertically integrated agricultural holding of Ukraine and information in [13], determine the time of grain delivery from

senders (farmers) to the port station Odessa-Port with overload on the Odessa port grain terminal, and further – to the Netherlands. It should be considered that the cargo is delivered from the Odessa port to the Netherlands ports by means of ships (Fig. 4). You must find out the most appropriate type of transport for each operation stage.

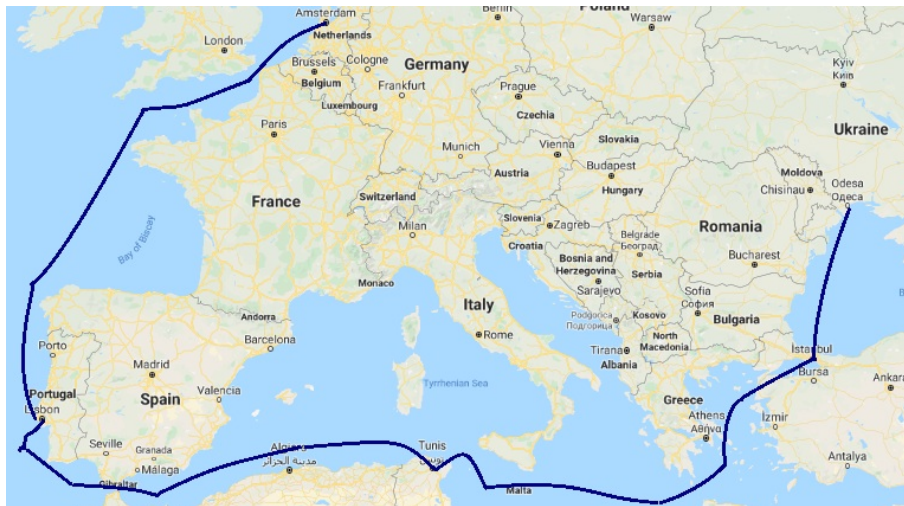


Fig. 4. Scheme of agro-products transportation from the Odessa-seaport to the Netherlands-port

Some solution ways. For statistical estimation of the values of the used parameters given in the models transitions – T_i , they are expediently divided into groups by characteristic feature (Table 1). The initial values in the positions (P_i) can be determined by the availability of statistical information of Ukrzaliznytsia, as well as by data of delivery information services.

The complex system analysis based on the Petri Nets environment can be performed with the use of simulation model. In line with this strategy, it is evidently needed to specify the input flows of demands and determine the system response. The initial parameters will be able to calculate processing the statistical material accumulated during the simulation.

Apparently, if it has a good chance to use both a road and a rail transport, then there are three variants of cargo flow distribution in the appropriate logistic systems of agro-products delivery. They are:

- Option 1 – 100% of cargo is transported by rail across the Ukraine.
- Option 2 – cargo is transported equally for each mode of transport (rail and road).
- Option 3 – 100% of the cargo is transported by road.

For all of those options, the models can be built in the Petri Nets environment. As a modeling result, the data distributed over the duration of execution of basic technological operations throughout the logistic system were obtained.

Case-study 2. You should analyze the behavior of the model depending on the volume of order the agricultural products delivery (Fig. 5) and determine the best variant of the grain cargo delivery chain from the sender toward the recipient

(destination port). The number of values is 54 units, it is determined by the level of confidence probability, error, and number of observations. The value of transport volume varies from 20 to 3240 tons [13].

Table 1. The model parameters statistical estimation

Parameter group name	Sample volume, units	Limits of the parameter's mathematical expectation values	Distribution law
Intensity of receiving orders, units / h.	68	0,2-6	Exponential
Intensity of agro-products receipting from collection and storage sites, t / h.	83	10-42	Exponential
Intensity of cars arrival, units / h.	49	1-5	Exponential
Intensity of wagons and locomotives arrival, units / h.	152	0,4-32	Exponential
Arrivals and departures of trains, units / h.	91	0,1-2	Exponential
Intensity of arrival or departure of vessel, units / h.	47	0,1-1	Exponential
Time for performance of harvesting technological operations, h.	72	8-53	Exponential
Time for performance of technological operations at storage in specialized places – in the warehouses, elevators, h.	59	0,5-28	Normal
Time for performance of technological operations on car, h.	63	0,2-34	Normal
Time for performance of technological operations on railway transport, h.	82	0,7-77	Normal
Time of carrying out technological operations on sea transport – into the ports, h.	51	1,3-164	Normal
Time for performance of technological operations during moving between ports, h.	37	320-384	Lognormal

Some solution ways. From the histogram (Fig. 5) the best option of the delivery model can be chosen. The choice should be made according to the criterion of minimum time for agro-products delivery. Meanwhile, it is possible to clearly trace the trend concerning parameter at position “30”, which corresponds to a cargo volume about 1470 tons. Under these terms, transportation by road is more advantageous. For larger volumes, it is advisable to deliver cargo to the port by rail only. In this case the usage of trucks is unacceptable alternative since this is due to the need to have a significant number of trucks, which for Ukrainian transport operators is inefficient.

The presented above approach allows to decide not only the timing scheme, but also to estimate directly the possible costs associated with determining the cost of delivery in terms of existing resources.

These, and simpler, case-study that are created on fact data and solved into the Petri Nets environment can be used as a basis for organizing future transport industry specialists' study and research activities. In next time students will be able to independently look at the current important information about cargo delivery and use

it to estimate various logistical models with the help of simulation into the Petri Net environment.

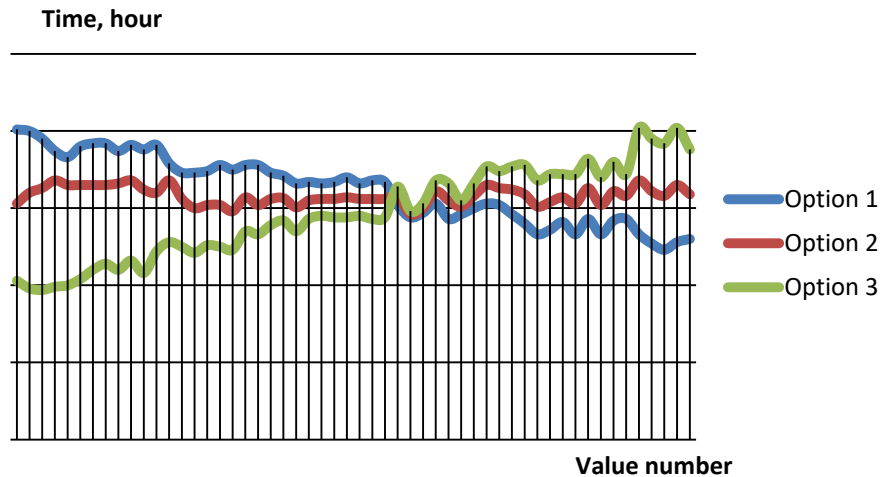


Fig. 5. The logistic system modeling results for three options of agro-products delivery with usage of Petri Nets app

5 Conclusions

It is established, in the context of increasing the intensity of transport flows and the widespread of ICT, the approaches to the modeling of logistic transport systems need to be qualitatively updated. From one part, globalization and information processes do affect the content and methods of vocational training of future specialists for transport industry.

It is found out that in Ukraine the logistic system of the agricultural products delivery has a structure based on the principles of alternative subsystem construction. The operation of each subsystem individually, as well as in the interaction is most effectively described with exploitation of the Petri Nets, which are used to investigate the behavior of an object in real time.

The paper presents an analysis of the theoretical foundations of the Petri Nets and the adequacy of their application for the transport processes simulation. It is shown that the Petri Nets allow to study in depth the behavior of a simulated system and to obtain information about its most important characteristics. It also takes into account that the logistic systems for the agricultural products delivery should be considered as systems for parallel processing of information and parallel operation of facilities. Modeling via the Petri Nets enables to track and analyze the results, the same way as to predict and control the forwarding cargo process (e.g. agricultural products) in various logistic systems.

The advantages of the Petri Nets app are the low complexity of model development and the possibility to simulate adequately, even with a small amount of source information. During the simulation it was found that this tool allowed to analyze and to forecast the work for all system participants, to calculate quickly the parameter values for each specific control object in logistic system.

As an example, it's provided the case-study set concerning simulation in three options agro-products delivery from Ukraine to the Netherlands with the use of the Petri Nets environment. The set can be applied in the system of students' study and research activities in transport area of expertise.

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Combining Programming and Mathematics Through Computer Simulation Problems

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Abstract. Nowadays, educators often use different computer algebra systems for teaching advanced math topics for CS students, and as a tool for solving math problems and providing research. Computer algebra systems allow the students to practice skills both programming and mathematics, that help to develop main components of computational thinking (decomposition, pattern recognition, abstraction, and algorithms). We provide the example of the use one of CAS (Mathematica) for the mathematical research on the $D(s)$ -function associated with Riemann Zeta function. For solving this problem, we need to find the algorithm in order to get a mathematically correct results generated by Mathematica.

Keywords: Computer algebra system (CAS), Mathematica, Wolfram software, computational thinking, numerical computing, Riemann zeta function, zeta effect.

1 Introduction

Today technically competent young people can easily use digital devices, know how to connect to GPRS, GPS and start streaming video. At the same time, educators say that traditional forms of educational cognitive activity have fallen. In the 20th century the core skills, that every person needed, were the abilities to read, to write and to count – so-called “3R’s” (Reading, wRiting, aRithmetic). In the 21st century another core skill – Computational Thinking (CT) – was added to these 3R’s. CT, which implies a new way to solve emerging problems with the methods of computer science and engineering, information technology, information systems. First the term “Computational thinking” was introduced in [1]. Seymour Papert discussed new pedagogical approaches in mathematical education in the paper [1]. This term denoted a way of thinking for the algorithmic solution of complex mathematical problems. Later Jeannette M. Wing in the paper [2] developed the computational thinking approach beyond mathematics.

In the paper [3] authors outlined that research team at MIT had developed computing environments designed to facilitate computational thinking (Logo, Scratch) and the use of computer as a computational object. Main components of computational thinking are

decomposition, pattern recognition, abstraction, and algorithms. Decomposition demonstrates how to divide complex problems into smaller problems. Pattern recognition shows how to find connections between similar problems and how to use previous experience. Abstraction helps to focus only on the important information without irrelevant details. Using algorithms, we can develop a step-by-step solution to the problem, or the road map to solve the problem.

Computational thinking and programming allow students to learn not only math and programming languages but help them to learn in order to become successful.

For some aspects of computer science students need to know mathematics that is a fundamental course in the educating process of CS professionals. Math helps programmers to solve a problem in an efficient way. Discrete math (set theory, logic, combinatorics), number theory (cryptography and security), geometry (geometric objects, transformations, rotations), linear algebra (matrices, series, differential equations), game theory etc. are math fields that are most important and commonly using in computer science. Math is not directly used in computer science. But computer science students have to think logically and analytically for being good programmers. These are the same types of thinking in solving difficult mathematical problems. Without math, students will face a longer learning curve in programming and vice versa.

In the papers [4], [5], [6], [7] authors provided an overview of educational aspects of math teaching and learning with integrated platforms and computer aided learning software.

Studies related to the effect of computer algebra systems (CAS) on learning efficiency of computer science students presented in papers [8], [9], [10]. The papers [11], [12], [13], [14], [15] presented how to use Mathematica and other CAS for solving math analytical and numerical problems. The ways of using Mathematica as a tool for visualization of the results of the different types of mathematical researches are described in [16], [17], [18], [19], [20], [21], [22], [23]. Some issues about organization of the workspace of a computational system are presented in [24]. There is a bibliography of publications about the Mathematica symbolic algebra language in the [25]. Special advanced math researches using Mathematica as a tool for computing are presented in papers [26], [27], [28], [29], [30]. Topics of the instability that is related to the well-known Gibbs phenomenon [31], [32] and is not in the specifics of the CAS, are presented in [26], [27], [28].

The paper is organized as follows. Section 2 details the advantages of using a computer algebraic software for solving math problems and presents a brief review and comparison of computer algebraic systems. Section 3 presents an advanced math problem that was solved using Mathematica as a main tool. In this section we illustrate the methods and results.

2 Programming, math and computer algebra systems

One way to implement the paradigm of the computational thinking is the use CAS for teaching mathematics and programming at CS departments.

Computer algebra system is a software that helps to manipulate mathematical expressions and mathematical objects, to provide symbolic or numeric computations, to plot different graphics and to visualize math objects. CAS may be divided into two classes:

- specialized, that can be used for solving specific problems of mathematics or statistics;
- general-purpose that can be used for a scientific domain that requires manipulation of mathematical expressions or objects.

The main features of general-purpose CAS are

- a user interface, allowing to enter math formulas or data, and graphics capability;
- a programming language and interpreter;
- a memory manager and garbage collector;
- a rewrite system for simplifying mathematics formulas;
- a large library of mathematical algorithms, special functions, efficient data structures;
- an arbitrary-precision (bignum) arithmetic, needed for calculations are performed on the huge size numbers;
- a fast kernel.

You can see a comparison of most popular CAS in the table 1.

Maple [33] was released by Maplesoft in 1982 as a symbolic and numeric computing environment. It is based on a kernel (written in C) and has libraries (written in Maple language) for performing technical and numeric computations. For storing symbolic expressions Maple uses such data structure as directed acyclic graphs. Maple's interfaces are written in Java. Maple software allows to analyze, explore, visualize, and solve mathematical problems. It can be used in mathematics, smart document environment, application areas, application development, high performance computing, connectivity and education.

Mathcad [34] is computer software product of the Parametric Technology Corporation (PTC) first introduced in 1986. It is used for engineering calculations; results are stored as a notebook. Equations and expressions are created in a worksheet and manipulated in the same graphical format.

The Mathcad functionality contains:

- numerous numeric functions covering such areas as statistics, data analysis and image processing;
- systems of equations (including ordinary and partial differential equations);
- roots of polynomials and functions finder;
- symbolical calculation and manipulation of math expressions;
- parametric, 2D and 3D plotting;
- vector and matrix operations (including eigenvalues, eigenvectors);
- statistical functions, regression analysis on experimental datasets.

Table 1. Popular computer algebra systems

Name of CAS / creator	First / Latest releases	Latest version	Price	License	Notes
Maple / Maplesoft	1984 / 2020	2020.0 (March 2020)	\$2,390 (Commercial), \$2,265 (Government), \$995 (Academic), \$239 (Personal Edition), \$99 (Student), \$79 (Student, 12-Month term)	Proprietary	For symbolic and numeric computing. Written in C, Java, Maple
Mathcad / Mathsoft, PTC	1985 / 2019	6.0.0.0 (October 2019)	\$1,600 (Commercial), \$105 (Student), Free (Express Edition)	Proprietary	Includes some of the capabilities of CAS. For numerical computing of the engineering problems
Mathematica / Wolfram Research	1988 / 2020	12.1.0 (March 2020)	\$2,495 (Professional), \$1095 (Education), \$295 (Personal), \$140 (Student), \$69.95 (Student annual license), free on Raspberry Pi hardware	Proprietary	For solving problems in many technical, scientific, engineering, mathematical, and computing fields. Written in Wolfram Language, C/C++, Java
SageMath / William Arthur Stein	2005 / 2020	9.1 (May 2020)	Free	GNU GPL	Open-source system with features covering many aspects of mathematics, including algebra, combinatorics, graph theory, numerical analysis, number theory, calculus and statistics. Written in Python, Cython
Symbolic Math Toolbox (MATLAB) / MathWorks	2008 / 2020	R2020a (March 2020)	\$3,150 (Commercial), \$99 (Student Suite), \$700 (Academic), \$194 (Home)	Proprietary	For solving and manipulating symbolic math expressions and performing variable-precision arithmetic.
SymPy / Ondřej Čertík	2007 / 2020	1.6 (May 2020)	Free	modified BSD license	Open-source Python library for symbolic computation.
Wolfram Alpha / Wolfram Research	2009 / 2020	2020	Pro version: \$4.99 per month, Pro version for students: \$2.99 per month	Proprietary	Online computational platform or toolkit that encompasses computer algebra, symbolic, numerical computation, visualization.

Wolfram Mathematica [35] is an application for mathematical symbolic calculations that consists of two parts – kernel (back end) and interface (front end). In general, Mathematica is a great tool for solving problems, it integrates all functionalities such as symbolic calculations, manipulations with equations, numeric and graphical outputs. Mathematica offers predefined functions for mathematics, physics, economy, biology and other areas. It is used for calculations in the scientific, engineering, mathematical and computer fields. The Mathematica is also called the CAS Mathematica uses the Wolfram Language. Wolfram Language is a multi-paradigm programming language developed by Wolfram Research for symbolic computing, functional and logical programming, which allows the implementation of arbitrary data structures.

SageMath [36] is free and an open source, python-based alternative to Mathematic, Mathcad, Maple. It uses many python packages, for example, Numpy, Matplotlib, Scipy, PyLab. SageMath has features covering many parts of mathematics – algebra, combinatorics, graph theory, numerical analysis, number theory, calculus and statistics.

MATLAB (MATrix LABoratory) [37] is a software package for high performance numerical computation. It provides an interactive environment with hundreds of built in functions for technical computation, graphics and animation and easy extensibility with its own high-level programming language. MATLAB contains a lot of tools for linear algebra computations, data analysis, signal processing, optimization, numerical solution of Ordinary Differential Equations (ODEs), quadrature and many other types of scientific computations. MATLAB also provides matrix manipulations, parametric, 2D and 3D plotting of functions and data, algorithms implementation, creation of GUI, and interfacing with programs written in other programming languages (C, C++, C#, Java, FORTRAN, Python).

SymPy [38] is an open-source library for symbolic computation that completely written in Python. It provides computer algebra (algebra, matrices, etc.) capabilities either as a standalone application, as a library to other applications, or live application on the web. The SymPy library is split into a core with many optional modules (polynomials, calculus, solving equations, discrete math, matrices, geometry, plotting, physics, statistics, combinatorics, printing).

Wolfram|Alpha [39] is a computational knowledge engine (answer engine) developed by WolframAlpha LLC. Wolfram|Alpha is an online service like a fact-based engine. It answers factual queries directly by computing the answer and does not provide a list of documents or web pages like search engine. Wolfram|Alpha uses technologies that can be divided into four key general areas: a data curation pipeline, an algorithmic computation system, a linguistic processing system, an automated presentation system.

CAS can run under different operating systems natively without emulation. Like most modern apps, Mathematica (except mobile OS), SageMath (except mobile Android OS), MATHLAB (except mobile OS), SymPy run on almost all commonly used OS. Maple, Mathcad do not have versions that run under Android, iOS and SaaS. Moreover, Mathcad does not have versions running under macOS, Linux. We provide a list of OS supporting CAS discussed above (Table 2).

To demonstrate the development of CT skills in teaching CS students advanced topics of mathematics, as well as the development of a heuristic, logical and algorithmic

thinking, we used Mathematica 12.0 to solve math problems, which may result in meaningful mathematical problems that lie outside the capabilities of the Wolfram Mathematica, or programming problems will appear that also lie outside the scope of the Wolfram Mathematica, which the CS student have to learn how to solve.

Table 2. Operating systems supporting CAS

CAS	OS						
	DOS	Windows	macOS	Linux	Android	iOS	SaaS
Maple	–	+	+	+	–	–	+
Mathcad	+	+	–	–	–	–	–
Mathematica	–	+	+	+	–	–	+
SageMath	–	+	+	+	–	+	+
Symbolic Math Toolbox (MATLAB)	–	+	+	+	+	–	+
SymPy	–	+	+	+	+	+	+

3 Math project “On the function $D(s)$ associated with Riemann Zeta function”

We used CAS (Mathematica 12.0 [35]) for investigating the $D(s)$ -function associated with Riemann Zeta function. Results of the project are presented in paper [26].

Let us consider the function $D(s)$ of the complex argument $s=\sigma+it$, formed with the use of a certain procedure of a transition to the limit:

$$D(s) = (1-s) \lim_{N \rightarrow \infty} \left(\frac{1}{N^{1-s} - 1} \cdot \sum_{n=1}^N \frac{1}{n^s} \right). \quad (1)$$

It is obvious that for $\sigma > 1$ the limit of the sum in (1) turns into the Riemann zeta function, and, accordingly:

$$D(s) = (s-1)\zeta(s), \quad (\text{Re } s > 1). \quad (2)$$

Where $\zeta(s) = \sum_{n=1}^{\infty} \frac{1}{n^s}$ is Riemann zeta function.

In the paper [26] was showed that for $\text{Re } s < 1$:

$$D(s) \equiv 1 \quad (\text{Re } s < 1). \quad (3)$$

Therefore, the function $D(s)$, defined by formula (1) in the entire complex plane (with the exception of the straight line $\sigma=1$), in the right-hand half-plane ($\sigma > 1$) in accordance with formula (2) differs from the Riemann zeta function only by the factor $(1-s)$, and in the left half-plane, in accordance with formula (3), it is equal to one. Formula (1), in

a certain sense, extends the Riemann series $\sum_{n=1}^{\infty} n^{-s}$ to the entire complex plane s (except for the straight line $\sigma=1$).

It is convenient to divide the real and imaginary parts of the function D :

$$D(s) = R(\sigma, t) + iI(\sigma, t) \quad (4)$$

where

$$\left. \begin{aligned} R(\sigma, t) &= t \cdot B(\sigma, t) + (\sigma - 1)A(\sigma, t), \\ I(\sigma, t) &= t \cdot A(\sigma, t) - (\sigma - 1)B(\sigma, t), \end{aligned} \right\} \quad (5)$$

A and B are the real Riemann series:

$$\left. \begin{aligned} A(\sigma, t) &= \lim_{N \rightarrow \infty} \sum_{n=1}^N \frac{\cos(t \ln n)}{n^\sigma}, \\ B(\sigma, t) &= \lim_{N \rightarrow \infty} \sum_{n=1}^N \frac{\sin(t \ln n)}{n^\sigma}. \end{aligned} \right\} \quad (6)$$

It follows from (6) that the series $A(\sigma, t)$ and $B(\sigma, t)$ have very simple asymptotics for large values of σ :

$$\left. \begin{aligned} A(\sigma, t) &\rightarrow 1, \\ B(\sigma, t) &\rightarrow 0, \end{aligned} \right\} \sigma \rightarrow \infty.$$

Consequently, in accordance with formulas (5), the asymptotics of $D(s)$ for $\sigma \rightarrow \infty$ and fixed t has the following form:

$$\left. \begin{aligned} R(\sigma, t) &\cong \sigma - 1, \\ I(\sigma, t) &\cong t. \end{aligned} \right\}$$

When calculating the function $D(s)$ in the right half-plane of the complex argument s (for $\sigma > 1$) we used finite-dimensional approximations of the oscillating real Riemann series (6). Instead of formulas (6) containing the limiting transition $N \rightarrow \infty$, we used finite sums:

$$\left. \begin{aligned} A_N(\sigma, t) &= \sum_{n=1}^N \frac{\cos(t \ln n)}{n^\sigma}, \\ B_N(\sigma, t) &= \sum_{n=1}^N \frac{\sin(t \ln n)}{n^\sigma}. \end{aligned} \right\} \quad (7)$$

When computing the sums A_N and B_N we usually fix N in the range between $N = 10^5$ and $N = 10^6$. A calculation with a smaller value of N introduced noticeable distortions

in the results. Computations with large values N required an unacceptably high time-consuming result. For N in the range $10^5 - 10^6$ one calculation, – for example, plotting the dependence of $R(t)$ for fixed σ and $0 \leq t \leq 50$ – requires, depending on σ and N from several tens of minutes to several work hours for Mathematica. You can see codes of plotting the R -function at listing 1, and symbolic results at Fig. 1.

Listing 1. Codes for plotting the R -function as the function of the argument t for $\sigma \gg 1$.

```
A[x_, y_] = N[Sum[{Cos[y Log[n]] / n^x}, {n, 1, 600000}]]
B[x_, y_] = N[Sum[{Sin[y Log[n]] / n^x}, {n, 1, 600000}]]
R[x_, y_] = y B[x, y] + (x - 1) A[x, y]
Plot[R[1.05, y], {y, 0.01, 50}, PlotTheme -> "Monochrome",
PlotRange -> Automatic, Axes -> True, AxesLabel -> {t, R},
LabelStyle -> {14, GrayLevel[0]}, Frame -> False, PlotLegends -> "Expressions"]
```

[Debug] Out[]:=

```
{ (-1 + x)
(1. + 2.-1. × Cos[0.693147 y] + 3.-1. × Cos[1.09861 y] + 4.-1. × Cos[1.38629 y] +
5.-1. × Cos[1.60944 y] + 6.-1. × Cos[1.79176 y] + 7.-1. × Cos[1.94591 y] +
8.-1. × Cos[2.07944 y] + 9.-1. × Cos[2.19722 y] + 10.-1. × Cos[2.30259 y] +
11.-1. × Cos[2.3979 y] + 12.-1. × Cos[2.48491 y] + ... 599977 ... +
599990.-1. × Cos[13.3047 y] + 599991.-1. × Cos[13.3047 y] +
599992.-1. × Cos[13.3047 y] + 599993.-1. × Cos[13.3047 y] +
599994.-1. × Cos[13.3047 y] + 599995.-1. × Cos[13.3047 y] +
599996.-1. × Cos[13.3047 y] + 599997.-1. × Cos[13.3047 y] +
599998.-1. × Cos[13.3047 y] + 599999.-1. × Cos[13.3047 y] +
600000.-1. × Cos[13.3047 y]) + y (... 1 ... ) }
```

Fig. 1. Symbolic results of the R -function of the argument t for $\sigma=1.05$ ($N=6 \cdot 10^5$).

Fig. 2 demonstrates, in addition to real “slow” t -oscillations of sufficiently large amplitude, also the presence of an interesting effect of short-period “parasitic” oscillations of small amplitude. This effect (we called it the “zeta effect”) is generated by a sharp break in the Riemann series (6) for a finite (albeit sufficiently large) value of n , equal to the “cut-off parameter” N $N \cong 10^5 - 10^6$. In Fig. 2, these zeta oscillations significantly deform the dependence $R = R(t)$ up to $t \approx 15$, but are also noticeable at $t \gg 15$.

A qualitative explanation of the nature of the “zeta effect” is given in the paper [26]. In some extent, this “zeta effect” is one of the version of the Gibbs phenomenon related to the Fourier series theory [32].

How can we suppress these parasitic zeta-oscillations generated by the termination of infinite Riemann series (5)?

To suppress the zeta effect, we used “exponential β -damping”, replacing each term in the Riemann sums (7) with its “damped” expression:

$$\left. \begin{aligned} A_N(\sigma, t) \rightarrow A_{N,d}(\sigma, t, \beta) &= \sum_{n=1}^N \frac{\cos(t \ln n)}{n^\sigma} e^{-\beta \frac{n}{N}}, \\ B_N(\sigma, t) \rightarrow B_{N,d}(\sigma, t, \beta) &= \sum_{n=1}^N \frac{\sin(t \ln n)}{n^\sigma} e^{-\beta \frac{n}{N}}. \end{aligned} \right\} \quad (8)$$

Where β is the damping parameter: $\beta > 1$. (In the calculations, we used the value $\beta=5$).

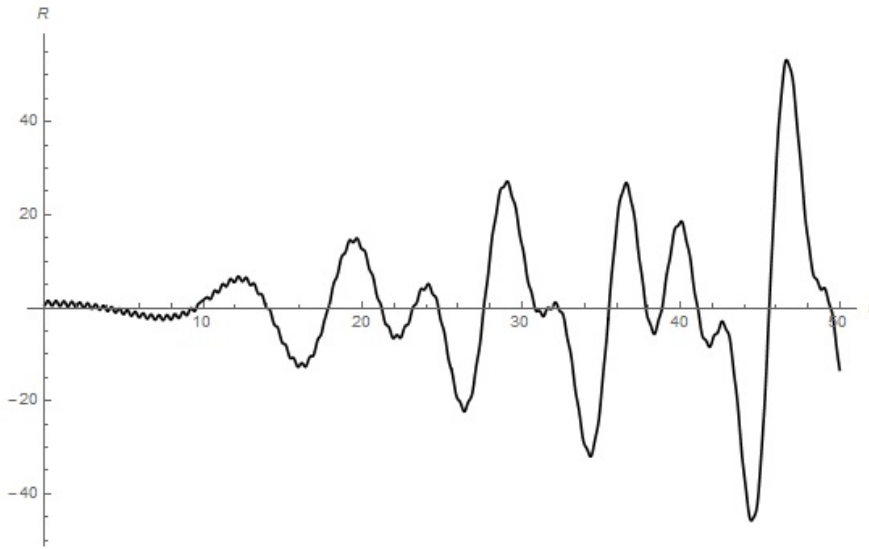


Fig. 2. The R -function as the function of the argument t for $\sigma=1.05$ ($N=6 \cdot 10^5$).

Exponential β -damping (8) does not significantly affect the contribution of the majority of “low-frequency” harmonics with $n \ll N$ and substantially reduces the contribution of terms with large numbers n , approaching to $n=N$. This method smooths out the effect of a sharp break in the Riemann series (5) for $n=N$.

Fig. 3 demonstrates the effect of exponential β -damping on the numerical results of calculating the function $D(s)$. This figure shows the same graph shown earlier in Fig. 2: dependence of the function R on the argument t for $\sigma=1.05$ and $N = 6 \cdot 10^5$. In Fig. 3 this dependence is calculated by the formulas (14), taking into account β -damping ($\beta=5$). The “smoothed” function $R(t)$ in this figure completely repeats the function $R(t)$ of Fig. 2 in all that concerns real large-scale slow oscillations, but is practically free of parasitic oscillations generated by the zeta effect. The trace of these parasitic oscillations remained only for small t ($t < 1$). The suppression of the zeta-effect in the region of small t requires an increase in the damping parameter β . An increase in β can cause distortion in real large-scale oscillations of the function $R(t)$. Here, the researcher must compromise, determining what is more important in a particular task – total suppression of the zeta-effect at small t or preservation of correct results for large t .

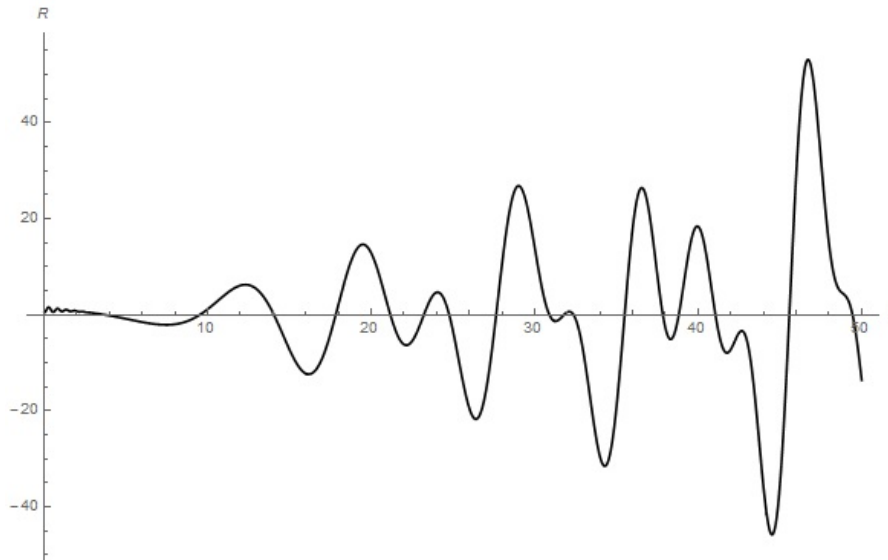


Fig. 3. The dependence of the function R of argument t for $\sigma=1.05$ ($N=6 \cdot 10^5$). The dependence is calculated using the exponential β -damping procedure described in the article for $\beta=5$.

4 Conclusions

Of the many problems that the author had to solve (on her own or in collaboration with colleagues and students) using various CAS packages, the author chose one problem here for purely illustrative purposes. In this task, the mathematics package used by itself works flawlessly, but you need to reflect on the algorithm in order to get a mathematically correct result using this package that suppresses some kind of pure instability. This instability is inherent in the task itself, and not in the specifics of the Mathematics package. In some sense, this instability is related to the well-known Gibbs phenomenon, which consists in a certain instability of the process of numerical summation of Fourier series in some situations.

In other problems, there may be situations where Wolfram Mathematica cannot perform certain actions at all (for example, plotting a curve containing cusp [27]) or perform calculations with the necessary accuracy in a reasonable time (for example, constructing fractal curves defined by Riemann-Weierstrass series).

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Guessing Games Experiments in School Education and Their Analysis

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Abstract. The paper deals with experimental game theory and data analysis. The research question is how different pools of players understand strategic situations, they never faced before. We examine data from a number of strategic interactions (games) and present players progress in finding solutions in competition with other players. We propose four “pick a number” games, all with similar-looking rules but very different properties. These games were introduced (in the body of scientific popular lectures) to very different groups. In this paper we present data gathered during lectures and develop tool for exploratory analysis using R language. Finally, we discuss the findings and open questions.

Keywords: behavioral game theory, guessing game, k-beauty contest, active learning, R.

1 Introduction

A key element of strategic thinking is to include into consideration what other agents do. Agent here is a person, who can make decisions and his/her actions have influence on the outcome. Naturally, person cannot predict with 100% what will others do, so it is important to include into model beliefs about other person thinking and update them during the game. Also, if we can't know what other player think, we can understand what is his/her best course of action. This is the main research topic of game theory.

All this makes decision making very interesting problem to investigate. In this work we will apply game theory to analyze such problems. Game theory provides mathematical base for understanding strategic interaction of rational players. There is important note about rationality, we should make. As Robert J. Aumann formulate in his famous paper [1], game theory operates with “homo rational”, ideal decision maker, who is able to define his/her utility as a function and capable of computing best strategy to maximize it. This is the main setup of game theory and one of major lines of criticism. In reality, of course, people are not purely rational in game theory sense. They often do not want to concentrate on a given situation to search for best decision or simply do not have enough time or capabilities for this. Sometimes they just copycat behavior of others or use some cultural codes to make strange decisions. Also (as we see from the experiments) it seems that sometimes homo sapiens make decisions with reasons, one

can (with some liberty in formulation) label as “try and see what happens”, “make random move and save thinking energy” and even “make stupid move to spoil game for others”.

This is rich area of research, where theoretical constructions of game theory seems to fail to work and experimental data shows unusual patterns. However, these patterns are persistent and usually do not depend on age, education, country and other things. During last 25 years behavioral game theory in numerous studies examines bounded rationality (best close concept to rationality of game theory) and heuristics people use to reason in strategic situations. For example we can note surveys of Vincent P. Crawford, Miguel A. Costa-Gomes and Nagore Iriberry [2] and Felix Mauersberger and Rosemarie Nagel [3]. Also there is comprehensive description of the field of behavioral game theory by Colin F. Camerer [4].

The guessing games are notable part of research because of their simplicity for players and easy analysis of rules from game theoretic perspective. In this paper we present results of games played during 2018-2019 years in series of scientific popular lectures. The audience of these lectures was quite heterogeneous, but we can distinguish three main groups:

- kids (strong mathematical schools, ordinary schools, alternative education schools);
- students (bachelor and master levels);
- mixed adults with almost any background.

We propose framework of four different games, each presenting one idea or concept of game theory. These games were introduced to people with no prior knowledge (at least in vast majority) about the theory. From the other hand, games have simple formulation and clear winning rules, which makes them intuitively understandable even for kids. This makes these games perfect choice to test ability of strategic thinking.

1.1 Game theory definitions

We will consider games in strategic or normal form in non-cooperative setup. A non-cooperativeness here does not imply that the players do not cooperate, but it means that any cooperation must be self-enforcing without any coordination among the players. Strict definition is as follows.

A non-cooperative game in strategic (or normal) form is a triplet $G = \{N, \{S_i\}_{i \in N}, \{u_i\}_{i \in N}\}$, where:

- N is a finite set of players, i.e., $N = \{1, \dots, N\}$;
- S_i is the set of admissible strategies for player i ;
- $u_i: S \rightarrow \mathbb{R}$ is the utility (payoff) function for player i , with $S = S_1 \times \dots \times S_N$ (Cartesian product of the strategy sets).

A game is said to be static if the players take their actions only once, independently of each other. In some sense, a static game is a game without any notion of time, where no player has any knowledge of the decisions taken by the other players. Even though, in practice, the players may have made their strategic choices at different points in time,

a game would still be considered static if no player has any information on the decisions of others. In contrast, a dynamic game is one where the players have some information about each others' choices and can act more than once. Summarizing, these are games where time has a central role in the decision-making. When dealing with dynamic games, the choices of each player are generally dependent on some available information. There is a difference between the notion of an action and a strategy. A strategy can be seen as a mapping from the information available to a player to the action set of this player.

Based on the assumption that all players are rational, the players try to maximize their payoffs when responding to other players' strategies. Generally speaking, final result is determined by non-cooperative maximization of integrated utility. In this regard, the most accepted solution concept for a non-cooperative game is that of a Nash equilibrium, introduced by John F. Nash. Loosely speaking, a Nash equilibrium is a state of a non-cooperative game where no player can improve its utility by changing its strategy, if the other players maintain their current strategies. Formally, when dealing with pure strategies, i.e., deterministic choices by the players, the Nash equilibrium is defined as follows:

A pure-strategy Nash equilibrium (NE) of a non-cooperative game $G = \{N, \{S_i\}_{i \in N}, \{u_i\}_{i \in N}\}$ is a strategy profile $s' \in S$ such that for all $i \in N$ we have the following:

$$u_i(s'_i, s_{-i}^0) \geq u_i(s_i, s_{-i}^0) \text{ for all } s_i \in S_i.$$

Here $s_{-i} = [s_j]_{j \in N, i \neq j}$ denotes the vector of strategies of all players except i . In other words, a strategy profile is a pure-strategy Nash equilibrium if no player has an incentive to unilaterally deviate to another strategy, given that other players' strategies remain fixed.

1.2 Guessing games

In early 1990th Rosemary Nagel starts series of experiments of guessing games, summarized in [5]. She wasn't the first one to invent the games, it was used in lectures by different game theory researchers (for example Hervé Moulin [6]). But her experiments were first experimental try to investigate the hidden patterns in the guessing game. Later, Teck-Hua Ho, Colin Camerer and Keith Weigelt [7] gave the name " p -beauty contest" inspired by Keynes comparison of stock market instruments and newspaper beauty contests. This is interesting quote, so lets give it here:

"To change the metaphor slightly, professional investment may be likened to those newspaper competitions in which the competitors have to pick out the six prettiest faces from a hundred photographs, the prize being awarded to the competitor whose choice most nearly corresponds to the average preferences of the competitors as a whole; It is not a case of choosing those which, to the best of one's judgment, are really the prettiest, nor even those which average opinion genuinely thinks the prettiest. We have reached the third degree where we devote our intelligences to anticipating what average opinion expects the average opinion to be. And there are some, I believe, who practice the

fourth, fifth and higher degrees.” (John Maynard Keynes (1936) “The General Theory of Employment, Interest and Money”, Chapter 12.V).

The beauty contest game has become important tool to measure “depth of reasoning” of group of people using simple abstract rules. Now there are variety of rules and experiments presented in papers, so lets only mention some of them.

2 Experiments setup

The setup is closer to reality then to laboratory and this is the point of this research. All games were played under following conditions:

1. Game were played during the lecture about the game theory. Participants were asked not to comment or discuss their choice until they submit it. However, this rule wasn't enforced, so usually they have this possibility if wanted;
2. Participants were not rewarded for win. The winner was announced, but no more;
3. During some early games we use pieces of paper, later we switch to google spreadsheets. The last tool has possibility to make multiple submission (with different names), but total number of submissions allows to control that.

The aim of this setup was to free participants to explore the rules and give them flexibility to make decision in uncertain environment. We think it is closer to real life learning without immediate rewards then laboratory experiments. Naturally, this setup has strong and weak sides. Let's summarize both.

The strong sides are:

1. This setup allows to measure how people make decisions in “almost real” circumstances and understand the (possible) difference with laboratory experiments.
2. These games are part of integrated approach to active learning, when games are mixed with explanations about concepts of game theory (rationality, expected payoff, Nash equilibrium etc), and they allow participants to combine experience with theory;
3. Freedom and responsibility. The rules doesn't regulate manipulations with conditions. So, this setup allows (indirectly) to measure how players cheat with rules or spend their time to solve the task.

Weak sides are:

1. Some percentage of players make “garbage” decisions. For example, choose obviously worse choice just to spoil efforts for others;
2. Kids has (and often use) possibility to talk out decision with the neighbors;
3. Sometimes participants (especially kids) lost concentration and didn't think about the game but made random choice or just didn't make move at all;
4. Even for simplest rules, sometimes participants failed to understand the game first time. We suppose it is due to conditions of lecture with (usually) 30-40 persons around.

Probably these weaknesses are inevitable in realistic scenarios. We claim that even if experiments are not in “pure” laboratory conditions, they reveal interesting behavior and are worth to introduce in this paper.

2.1 Rules of games

All games have the same preamble: Participants are asked to guess integer number in range 1 – 100, margins included. Note, that many setups, investigated in references, use numbers starting with 0. But the difference is small.

To provide quick choice calculation we have used QR code with link to Google Forms, where participants input their number. All answers were anonymous (players indicate nicknames to announce the winners, but then all records were anonymized). The winning condition is specific for every game.

1. **p-beauty contest.** The winning number is the closest to $2/3$ of average.
2. **Two equilibrium game.** The winning number is the furthest from the average.
3. **Coordination with assurance.** The winning number is the number, chosen by plurality. In case of tie lower number wins.
4. **No equilibrium game.** The winning number is the smallest unique.

All these games are well-known in game theory. Let’s briefly summarize them. First game is dominance-solvable game. Strategy “to name numbers bigger than 66” is dominated, since it is worse than any other. So rational player will not play it and everybody knows that. Then second step is to eliminate all numbers higher than 44 and so on. At the end rational players should play 1 and all win. In our setup we go further than just give players learn from observation. After first round we explain in detail what is Nash equilibrium and how it affects the strategies. After this explanation all participants actually **knew** that choosing 1 is the equilibrium option, when everyone wins. We supposed, that this should help to improve strategies in next round, but it is not.

Second game is about mixed strategies. Easy to show that if you want to choose number smaller than 50 – best way is to choose 1, since all other choices are dominated. And if you want to choose number bigger than 50 – best idea is to choose 100. Also, it is meaningful to choose 50 – it almost never wins. So, if many players will choose 1 – you should choose 100 and vice versa. In this game the best way to play is literally drop a coin and choose 1 or 100.

Third game has many equilibriums, basically every number can be winning. But to coordinate players must find some focal points (Thomas C. Schelling [8]). Natural focal point (but not only one!) is the smallest number since smaller number wins in case of tie. This slim formulation allows nevertheless make successful coordination in almost all experiments.

Finally, last game is in a dark water. As far as we know there is no equilibrium or rational strategy to play it. So sometimes very strange numbers are winners here.

3 Results and data analysis

3.1 First game

First game results are given in the Table 1.

Table Error! No sequence specified.. Results for p-beauty contest game.

Pool of players	Round	Mean	Winning number	Participants amount	Percent of irrational (> 66) choices
Alternative humanitarian school	1	66.69	66.69	13	61.5
	2	3.91	3.91	12	0
	3	3.07	2.05	13	0
Alternative mathematical school	1	42.82	28.54	17	11.7
	2	24.37	16.24	16	0
Adults	1	40.57	27.05	19	10.52
Alternative humanitarian school	1	52.54	35.02	11	27.2
	2	15.41	10.27	12	8.33
Adult (Facebook online)	1	22.98	15.32	102	4.9
Ordinary high school	1	43.41	28.94	51	23.5
	2	46.5	30.99	62	33.8
Mathematical school 1	1	43.41	28.94	51	23.5
Mathematical school 2	1	30.58	20.38	50	8
	2	14.26	9.5	57	5.26
Mathematical school 3	1	37.07	24.71	29	6.89
	2	26.2	17.47	29	6.89
Mathematical school 4	1	42	27.99	18	16.6
	2	23.1	15.39	20	0
Ordinary school	1	48.6	32.46	26	23
	2	19.78	13.18	23	0
Adults (conference on data science)	1	37.25	24.83	60	15
	2	21.44	14.29	57	12.28
IASA KPI (BSc)	1	42.4	28.27	27	22.2
NAUKMA (MSc)	1	27.37	18.24	8	12.5
	2	8.62	5.74	8	0

Almost all winning numbers are fall (roughly) in the experimental margins, obtained in Rosemary Nagel work [5]. With winning number no bigger than 36 and not smaller than 18 in first round. Two exceptions in our experiments were Facebook on-line test (15.32), when players can read information about the game in, for example, Wikipedia. And other is alternative humanitarian school (66.69), which seems didn't got the rules from the first time.

Using R statistical visualization tool, we can analyze in details how players from different types change their decisions between first and second round (Figure 1).

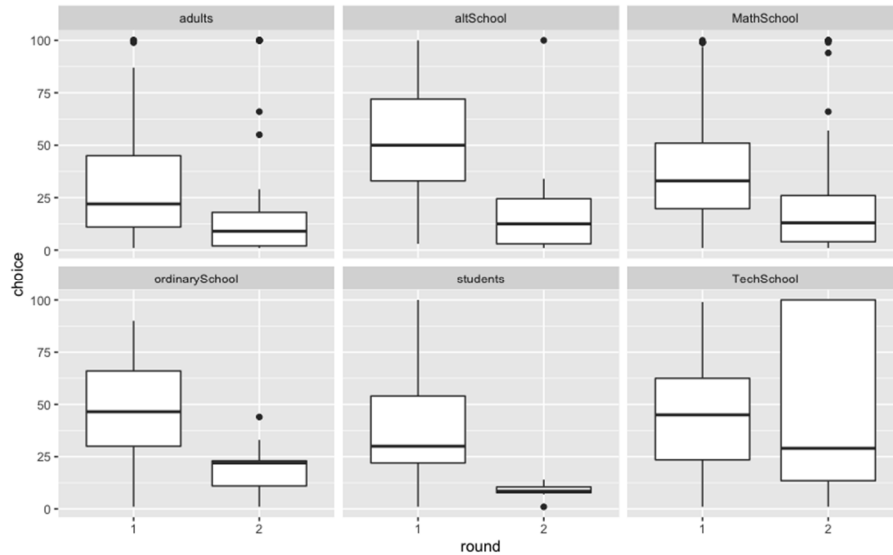


Fig. 1. Boxplot with two-round data about choice in first game.

Interesting metric is the percent of “irrational choices” – choices that can’t win in (almost) any case. Let’s explain, imagine that all players will choose 100. It is impossible from practice but not forbidden. In this case everybody wins, but if only one player will deviate to smaller number – he/her will win and others will lose. So, playing numbers bigger than 66 is not rational, unless you don’t want to win. And here we come to important point, in all previous experiments this metric drops in second round and usually is very low (like less than 5%) [8]. But in our case, there are experiments where this metric become higher or changes very slightly. And initially values are much higher than expected. So here we should include factor of special behavior, we can call it “let’s show this lector how we can cheat his test!”. What is more interesting – this behavior more clear in case of adult then kids.

It is also interesting to see distribution of choices for different types of groups. We can summarize choices on the histograms (Figure 2).

Another metric [9] is how much winning choice in second round is smaller than in first. Due to concept of multi-level reasoning, every player in this game trying to its best to win but can’t do all steps to winning idea. So, there are players, who just fight with nature. They think – let’s assume all players chose numbers in random, then 50 will be average and 33 will be winning choice. It is first level reasoning. Then they try to estimate how many players chose 33, and calculate that best response for it will be 22 (of course we should also include those who failed to do first step and make some random choice) and so on. Based on result of first round and, in fact, explanation about the Nash equilibrium, players must know that it is better to choose much lower numbers. But graph shows that decrease is quite moderate. Only students show good performance in this matter. And tech school shows increase in winning number in second round! (Figure 3)

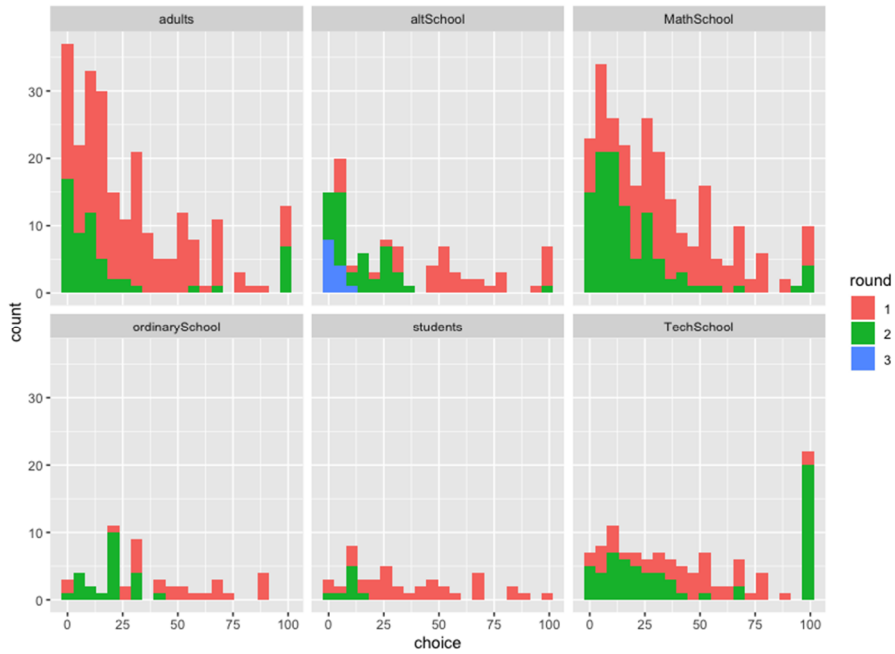


Fig. 2. Histogram of choices in first game for each type.

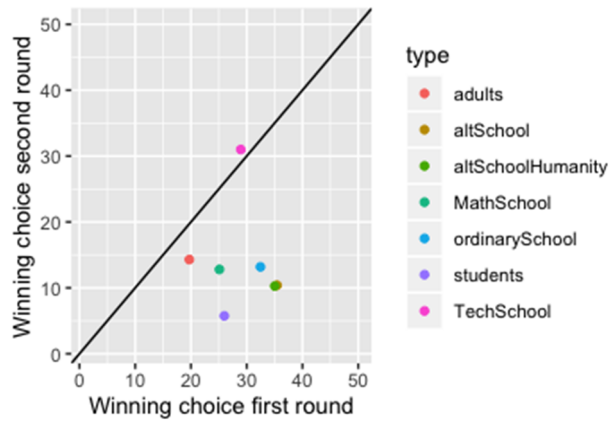


Fig. 3. Winning numbers in first and second round for each type.

3.2 Second game

In second game the key point is to understand that almost all strategies are dominated. The results are presented on Figure 4. and we can see that average can be bigger or smaller than 50, and accordingly winning choice will be 1 or 100. It is worth to note, that popular nature of these experiments and freedom to participate make the data

gathering not easy. For example, many participants just didn't take any decision in second game. Results summarized in next table.

Table 2. Results for second game.

Pool of players	average	Percent choose 1	Percent choose 100	Number of participants
adults	43.64912	21.05263	26.31579	171
altSchool	43.77778	25.92593	14.81481	27
MathSchool	48.55844	22.72727	24.67532	154
ordinarySchool	51.21739	30.43478	30.43478	23

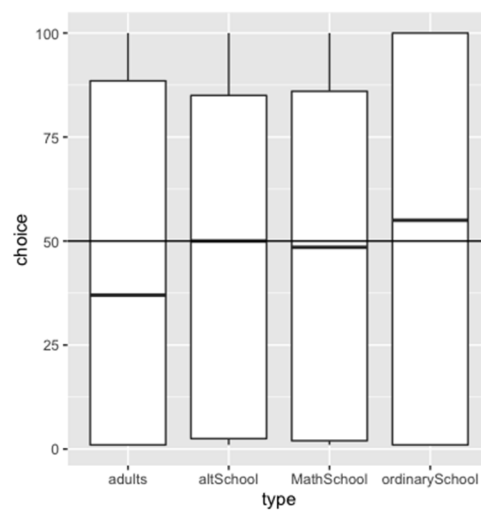


Fig. 4. Boxplot for choices in second game.

This is remarkable result, players without prior communications choose to almost perfect mixed equilibrium: almost the same percentage choose 1 and 100. This is even more striking taking into account no prior knowledge about mixed strategies and mixed equilibrium, kids play it intuitively and without any communication.

3.3 Third game

Third game is simpler than first two, it is coordination game where players should coordinate without a word. And, as predicted by Thomas Shelling, they usually do. Data presented on Figure 5 shows that 1 is natural coordination point, with one exception – Tech school (id = 1 here) decided that it would be funny to choose number 69 (it was made without single word). Probably, it is the age (11th grade) here to blame. Also, we can note attempt to coordinate around 7, 50 and 100.

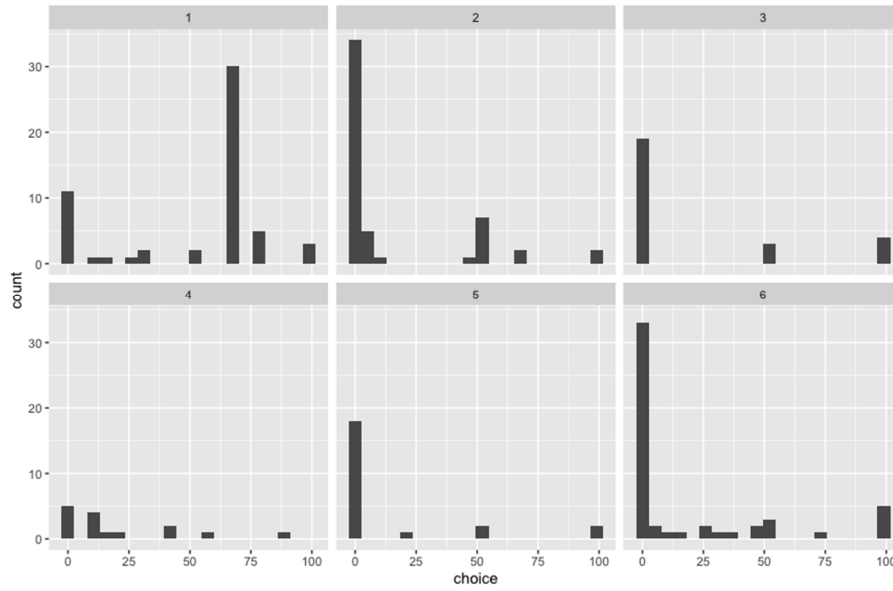


Fig. 5. Coordination game. Histograms of choices.

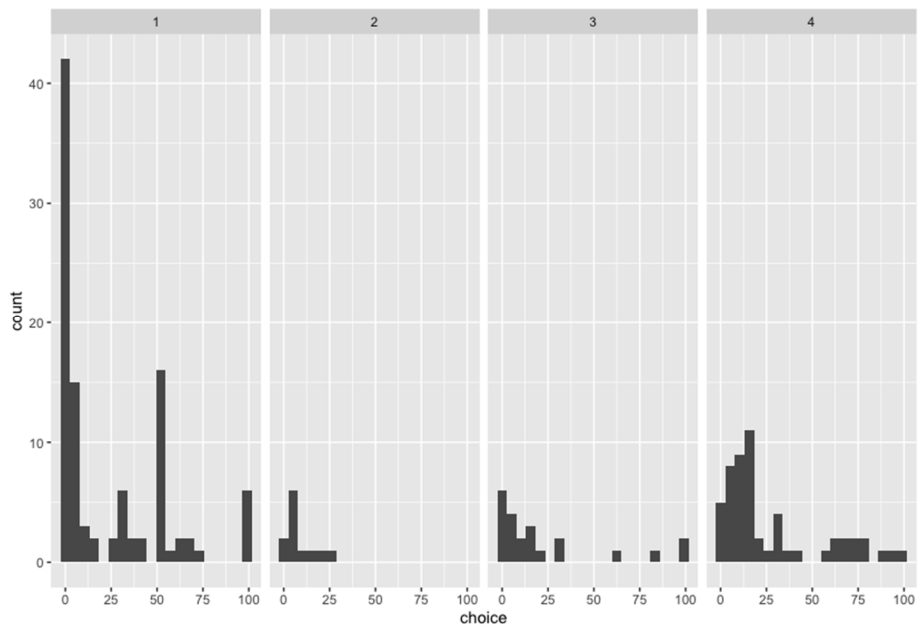


Fig. 6. Min unique game.

3.4 Fourth game

Here we just present the resulting histogram for each group and the winning numbers were: 12, 2, 4, 20 (Figure 6). Since no equilibrium here was theoretically found, we can only gather data at this stage and formulate hypothesis to found one.

All experimental data and R file for graphs can be accessed in open repository [10].

5 Conclusions

In this paper we have presented approach to make experimental game theory work for learning in educational process and be a research tool at the same time. Our result show classical pattern in decision making – actually every group behave in almost the same way dealing with unknown game. Some tried to deviate for unusual actions (like choosing 100 or choosing 69), and this is interesting point of difference with more “laboratory” setup of existing research. The main findings of the paper are following:

1. To learn the rules, you need to break them. Participants have chosen obviously not winning moves (> 66) partly because of new situation and trouble with understanding the rules. But high percent of such choices was present in second round also, when players knew exactly what is going on. This effect was especially notable in the cases of high school and adults and almost zero in case of special math schools and kids below 9th grade. We can formulate hypothesis that high school is the age of experimentation when children discover new things and do not afraid to do so.
2. If we considered winning number as decision of a group, we can see that group learning fast and steady. Even if some outliers choose 100, mean still declines with every round. It seems that there is unspoken competition between players that leads to improvement in aggregated decision even if no prize is on stake. Actually, it is plausible scenario when all participants choose higher numbers. But this didn't happen in any experiment. The closest case – Tech school, when bunch of pupils (possible coordinating) switch to 100 still only managed to keep mean on the same level.
3. In second game the surprising result is that players use mixed strategies very well. It is known (from experiments of Colin Camerer) that chimpanzee can find mixed equilibrium faster and better than humans. It seems that concept of mixed strategies is very intuitive and natural. But still in quite unfamiliar game players made almost equal number of 1 and 100, so each player unconsciously randomized his own choice.
4. In third game players coordinates to 1, as expected, because of condition that from numbers with equal choices – lesser wins. Also, we can note attempts of coordination around 7, 50 and 100. What is interesting is that in practice the condition was never applied – majority chooses 1 and that's it. If we decrease the numbers range to 1-10, other numbers have chance to win (5 or 7 for example). So, this is unexpected result – increasing of number of choices leads to bigger uncertainty when players trying to find slightest hint what to do, and this is condition of “lesser wins”. When

players apply this condition to big area, they probably think – “1 is perfect choice, and other will think in that way also, this increase chances of winning”.

The results have multiple applications:

- to provide kids with first-hand experience about strategic interactions and explain their decisions;
- to demonstrate how game theory experiments can be used in educational process;
- to understand difference in decision making among groups;
- to compare results with classical experiments and replicate them in modern Ukrainian education system.

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Application of Open and Specialized Geoinformation Systems for Computer Modelling Studying by Students and PhD Students

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Abstract. The article contains research on use of open and specialized geoinformation systems to prepare students and postgraduates on specialties: 101 “Environmental Sciences”, 103 “Earth Sciences”, 122 “Computer Sciences”, 183 “Environmental Technologies”. Analysis of the most common world open geoinformation systems is done. Experience of geoinformation systems use for students and postgraduates teaching for different specialties is described. Predominant orientation towards the use of geoinformation systems in educational process is determined based on the analysis of scientific publications and curricula of the most popular Ukrainian universities. According to the authors the material that is given narrows knowledge and skills of students and postgraduates, particularly in computer modeling. It is concluded that ability of students and postgraduates to use geoinformation systems is interdisciplinary. In particular, it develops knowledge and skills in computer modeling of various processes that may arise in the further professional activity. Examples of professional issues and ways to solve them using geoinformation systems are given. Recommendations are given on the use of open and specialized geoinformation systems in the educational process. It is recommended to use both proprietary (ArcGis, MapInfo) and open GIS (uDIG, QGIS, Whitebox GAT) to teach students. Open GIS (uDIG, QGIS, Whitebox GAT) and specialized

(Modular GIS Environment, GEO + CAD, GeoniCS, AISEEM) can be used to teach both students and postgraduates.

Keywords: geographic information system, computer simulation, open software, specialized geographic information system, training of students, graduate students

1 Introduction

Improvement of education quality is one of the most important issues in the development of Ukrainian society. The modern world is rapidly evolving and changing. Updating and improving of information technologies is performed almost each year. Therefore, the national higher education system does not have time to adapt curricula and plans to the requirements of the market and society. This problem is urgent in the field of specialists training: 101 “Environmental Sciences”, 103 “Earth Sciences”, 122 “Computer Sciences”, 183 “Environmental Technologies”.

For example, educational and professional training program of students of the specialty 122 “Computer sciences” is focused first of all on the preparation of competitive specialists with already formed professional competencies in the field of information technology. It should be sufficient for effective fulfillment of professional tasks in the design of information systems and their components. This program includes many aspects of training, ranging from mastering programming languages, software design methodologies, creation of ready-made software and technological solutions and their use in specific areas of activity (financial, consulting, logistics, etc.). One of the potential application areas of the knowledge of future specialists in the above-mentioned specialties is socio-ecological. It includes tasks related to ensure efficient use of natural resources, environmental protection, ensuring of authorities’ openness, land management and even more. It is important to use geoinformation systems and technologies to solve these problems efficiently.

Modern geoinformation systems (GIS) are not only systems for automated processing of geospatial data, vectorization and visualization of objects and events in real time mode. It is also a powerful complex of geospatial analysis, strategic support for managerial staff decision-making.

For Ukraine, the issue of development and implementation of GIS is relevant. It is emphasized in the following regulations: the Concept of the digital economy and society of Ukraine for 2018-2020 [15], the Concept of eGovernment development in Ukraine dated 20.09.2017 No 649-p [16], the Concept of creation of the national automated system “Open environment” [17], Decree of the President of Ukraine on “Sustainable Development Goals of Ukraine for the period up to 2030” dated 30.09.2019 No 5 [31] and others.

Higher education institutions are now required to enhance the geo-information vector of their students and postgraduate’s education, in particular, to use modern GIS and the software in teaching process. It would satisfy educational goals and professional competence of professionals to the maximum extent. Validity of specific software using in the learning process is conditioned by the knowledge and experience of the teacher

who teaches the GIS course. It is accepted that the Environmental Systems Research Institute with the ArcGis software product line is the world leader in the development and implementation of GIS. Therefore, the use of these products in the educational process will give students greater competitive advantage in the future [18]. It should be noted that according to the G2 Crowd analytical platform [5] in the GIS world market research the Google Earth Pro took first place, while ArcGis was second in the top rankings. In addition, according to experts and users ArcGis products are useful as corporate GIS and their licenses value is inaccessible to small and medium-sized businesses, budgets and other organizations in our country. We believe that student with skills of working in the ArcGis environment (convenient, thoughtful, with 24-hour service support) will simply not be able to work with another software environment, and during development will try to imitate principles of operation of the familiar system [46].

Therefore, it is important to develop the skills of working with undergraduate and graduate students with proprietary as well as open and specialized GIS. This will greatly enhance their practical experience and enable them to understand the mechanism of transformation of geospatial data, regardless of the type or type of GIS.

2 Literature analysis and problem statement

Geoinformatics, as a science, is relatively young in Ukraine. Therefore, educational and methodological materials are not developed sufficiently. Various aspects of the GIS use for solving environmental safety problems are discussed in [22, 28, 29, 30, 39, 41, 43]. Development of specialized GIS was described in publications [1, 40, 43]. Comparative characteristics of open source and proprietary software and their use in educational process are subject of research [9, 21]. Problems of GIS using in educational process for the preparation of different specialties students are revealed in the works: 101 “Environmental Sciences” [33], 122 “Computer sciences” [46], 183 “Environmental protection technologies” [10, 33] and others. Features of software for computer simulation of various processes are disclosed in [4, 19, 22, 24, 28, 42]. However, potential of open and specialized GIS using to teach computer modeling by is insufficiently disclosed and needs further investigation.

3 The aim and objectives of the study

Aim of the article is to select open and specialized GIS which should be used to teach computer modeling disciplines to students and PhD students.

Tasks of the research:

1. to analyze peculiarities of using open GIS in educational practice;
2. to compare characteristics of open GIS functionality;
3. to describe specific application of specialized GIS (for example, AISEEM);
4. to give examples of computer simulation by using specialized GIS in environmental monitoring tasks.

4 Research results

4.1 Application of GIS in education

GIS is one of the information systems types implemented on the basis of modern computer technologies to perform various tasks related to geospatial analysis. It is designed to create geographical thematic maps and analysis of objects of the real world, to monitor their state, to study the dynamics of events in real time, etc. [46].

The work [6] states that GIS is an automated information system based on geospatial data. Purpose to teach the discipline “GIS and database” is to study basic provisions and knowledge of modern development, patterns of construction and operation of information systems in general, and information systems related to the geospatial location of objects in particular and to make management decisions based on these systems in real time. Laboratory work on the discipline “GIS and Database” is performed in the software product ArcGIS 10.3. After discipline studying students should know: theoretical foundations of GIS construction; GIS functionality; GIS data collection tools; models of presentation of graphic information; GIS analysis and modeling capabilities; methods for creating of common and thematic maps using GIS. They should be able to: collect primary information for GIS; enter data into GIS; represent data of processing results; perform data analysis and modeling; use GIS to create generic and thematic maps and plans.

Syllabus of educational discipline “Ecological systems and GIS technologies” is done in accordance with educational and professional program of specialist of higher education “Master” of specialty 101 “Ecology” and 183 “Environmental protection technologies”. The subject is organization and functioning of ecosystems and use of GIS technologies in ecology. Discipline “Ecological systems and GIS technologies” gives students master program the opportunity to gain in-depth knowledge in the field of modern computer systems. It includes systems of spatial data processing and database management and skills in using these systems to solve various tasks of managing a balanced nature management [10, 33].

Teaching GIS basics to students of computer specialties is mainly concentrated in “Geoinformation systems” discipline. It can be stated based on the curricula of educational and vocational training programs for specialists in the specialty 122 “Computer Science”. The discipline is taught at the first (bachelor) and second (master) levels. It is given to bachelors in the 3rd semester of full-time study (for example, at National Technical University of Ukraine “Igor Sikorsky Kyiv Polytechnic Institute”, Vadym Hetman Kyiv National Economic University, in the 4th semester (e.g. Vinnytsia Institute of Economics), in the 5th semester (Zaporizhzhia National University); for masters it is given in the 3rd semester (discipline “Geoinformation systems and technologies in nature management”, The National University of Life and Environmental Sciences of Ukraine). The discipline is selective in all cases. It implies that the discipline is not necessary for students. The main tasks of the discipline “Geoinformation systems” for the specialty 122 “Computer sciences” are following: acquiring of the knowledge and skills necessary to work with modern GIS by students; development of spatial analysis capabilities and work with large data sets; formation of

theoretical and practical skills of independent development of elementary model of GIS (its prototype). On the basis of acquired knowledge students should be able to: choose methods and means of entering geological and geophysical data in digital and graphic formats; create prototypes (fragments) of GIS that perform certain application tasks; apply geoinformation methods to construct structural, parametric and thematic maps; perform various GIS (ArcGis, Saga GIS, MapInfo, Google Earth, QGIS, etc.) [46].

The article [8] discusses a need to amend curricula of higher education institutions in accordance with current requirements. Possession of software and ability to create variety of thematic maps with it and basic theoretical training in cartography is an integral competence of modern experts in the field of Earth sciences. Geoinformation education should be one of the system-forming factors in formation of students imaginative analytical system-spatial thinking. GIS education has specific features that distinguish it from other areas of training. Among them are: wide range of software applications; interdisciplinary nature; high information saturation, etc.

GIS specialists should have systematic knowledge and skills in the field of GIS design, operation and development. GIS education is aimed at: comprehensive solution of natural-economic and social problems; assimilation of new methods and data processing tools that provide high clarity of displaying heterogeneous information, processing and analysis of spatial information; use of modern means of operative solution of management problems, evaluation and control of surrounding processes [8].

Researchers point out [34] that the modern learning process cannot be imagined without innovation. These innovations typically develop dialectical approach in observing objects, phenomena, and real-world processes. The introduction of GIS into the teaching process assists students in observation, analysis and interpretation of spatial information. It is easier for students to study different subjects using GIS tools to model different processes. Students' academic performance becomes more effective due to GIS. They are motivated to learn new skills using modern technologies.

The publication [1] states that GIS is a window into the past, present and future. It facilitates access to information regarding natural, social and cultural aspects. In this way, GIS become indispensable when it comes to cognition, study and environmental quality. The authors describe the use of Google Earth in environmental education through creation of didactic routes taken by students at the University of Córdoba (Spain).

Analysis of the textbooks, manuals, laboratory workshops [24, 27, 32, 36] showed that question of open GIS use in the educational process is limited by analysis of classification approaches. Attention is paid to use of proprietary software GIS-complexes like ArcGis and MapInfo. Practical aspects of open GIS use in the educational process are disclosed only in [35] and [37]. Most of the available scientific and methodological developments are concentrated in the field of design and implementation of geoinformation GIS in practice, solving real scientific and applied problems [43, 7, 19, 22, 28, 39, 44].

Modern GIS have a wide range of capabilities. There is always a need to improve and complicate geoinformation systems, thus complicating calculations, increasing the number of operations per unit of time, thereby obtaining greater accuracy and reliability with the constant development of technology and increasing demands for information

systems. The most modern GIS perform complex information processing using the following functions: data input and editing, support of spatial data models, information storage, transformation of coordinate systems and transformation of cartographic projections, raster-vector operations, measurement operations, polygonal operations, spatial analysis operations, various types of spatial modeling, digital terrain modeling and surface analysis, presentation of results in various forms, and many different specific, depending on the recognition spare system modeling functions. Determining of maximum list of GIS requirements is one of the most important steps in modeling of such systems today. GIS offer rich selection of tools for processing of spatial information. Geo-processing is a key environment for modeling and analyzing location data. With this environment it is possible to synthesize data that cannot be obtained from one source or another [45].

Geoinformation modeling is a high-tech process of terrain model creating of certain territory in the environment of geoinformation systems. The created model visualizes quantitative and qualitative parameters of simulated terrain. It reflects intensity of the processes (e.g. hydrological, technological), gives an objective assessment of the state of the object (urban environment, individual components of the natural environment, human economic activity, etc.). Usually geoinformation modeling is a tool for decision making when developing recommendations for optimization of nature management, urban development, reduction of destructive anthropogenic impacts on the environment, prevention of man-made incidents and development of dangerous phenomena and processes [11].

One of the main strategic goals of geoinformation modeling is to see the whole. User can detect in-depth systemic relationships and trends that are unavailable for cognition using traditional methods of cognition using geoinformation modeling, with the introduction of a large amount of reliable and accurate data into the system. For example, the digital terrain model developed on the basis of GIS-modeling serves as a solid foundation for making decisions about the future state of territory. Geoinformation modeling can also provide: construction of phenomena density models; object location analysis; change modeling; distribution of objects by categories; search and definition of patterns of distribution of spatial and attribute data; analysis of the nearest neighborhood; defining spatial attributes of objects; three-dimensional visualization of the final results [11].

GIS integrate various data required in the decision-making process on spatial basis: characteristics of pollutant emissions in the region; regional geographical, socio-economic, ecological and medical-epidemiological characteristics. Use of GIS for displaying and analyzing pollution fields on electronic maps is common. Geoinformation systems are interesting in of information visualization. They provide visual representation of multidimensional environmental information. This is very useful during assessing of environmental risks and informing decision-makers. Thus, it is possible to distinguish the main GIS capabilities that are used in environmental quality management tasks: 1) preparation of data for analysis and modeling. GIS is used both to obtain and systematize information (regarding sources of pollutant emissions, surface characteristics) and to analyze and transform using powerful data display tools; 2) spatial analysis and modeling of the distribution or changes of the researched objects

and processes; 3) publication of results, which is a process of forming procedure where results of calculations and analytical research are transformed into user-friendly thematic maps. The maps are revealed in the pattern of analysis in the best possible way for decision-maker. Modern information systems often use GIS server technologies where processing of analysis results is process of forming client server procedure [25].

The publication [20] describes the use of GIS for measurement, modeling and mapping. Experience of teaching students to use GIS is presented, namely use of geographical positioning tools to determine location and integrate these measurements into GIS. The isee systems' STELLA Modeling software for forecasting tasks is also used.

The research [40] describes a CyberGIS system that combines cyber infrastructure, geoinformatics, spatial analysis, and modeling to provide research opportunities. It became the next-generation GIS, enabling better information retrieval, visualization and visual analytics, data management, and collaborative problem solving and management decision-making.

The main directions of GIS technologies application in modern conditions are described in [3]. The article presents various classifications of GIS, history of GIS technology development since the late 50's of the last century. Experience of GIS application in the state security service, emergency service, medicine, ecology and nature management, education, business is shown.

4.2 Characteristics of the open GIS

The main motive for development of the open GIS segment in the world is inability to meet all market needs by proprietary GIS including: small or non-profit organizations (scientific laboratories, educational institutions, government institutions) that are unable to acquire required number of licenses. This is also typical for Ukraine in background of understanding of importance and necessity of GIS in most fields of activity. There are not enough available resources for their implementation. Therefore, it is not expected that studying of ArcGis or MapInfo functionality at high user level will prepare future specialists for work. That is why we emphasize the need to use open and specialized GIS in the learning process.

Open source software is software with open code which can be read or modified by the user [26]. Features of open source software are: free distribution, available source code, permission to modify source code. Conditionally all open GIS can be divided into three classes: web (working through a web browser), desktop (installed on a computer), spatial databases (which contain geospatial data). Let's analyze desktop open GIS.

According to Monde Geospatial, 2017 [2] the list of open desktop GISs available in the world today exceeds more than 350 solutions. The most common are: GRASS GIS, QGIS, Whitebox geospatial analysis tools (Whitebox GAT), gvSiG, Saga GIS, ILWIS, MapWindow GIS, uDIG, etc. General characteristic of 5 open GIS is described in the following sentences. Functionality of presented open GIS is same to their commercial counterparts. All open GIS are updated and refined. It evidenced by analysis of the installation versions available in the network and how often they are updated. Architectural solutions of open GIS are characterized by a multilevel modular structure.

Features of open desktop GIS functionality:

1. QGIS. Purpose and Functionality: cartography (creation, design, modeling), support for raster, vector, geospatial analysis, plugins for procedure automation. Year of development: 2002. Number of tools available: >500. Supported operating system: Windows, Linux, Mac OS X, Android. Update: v. 3.10.2, release dated 10.2019. Programming language: C++. Presence of Ukrainian (Russian) translation of supporting documentation: Ukrainian – nominally, Russian – partially.
2. GRASS. Purpose and Functionality: creation, analysis of image design and graphics; geospatial analysis, data management support for work with raster, vector, satellite data. Year of development: 1982. Number of tools available: >300. Supported operating system: Windows, Linux, Mac OS X. Update: v. 7.8.2 release from 12.2019. Programming language: C. There is no Ukrainian (Russian) translation of supporting documentation.
3. Whitebox GAT. Purpose and Functionality: Educational and research goals, geospatial analysis, vectorization and image processing tools, spatial filters, multicriteria project evaluation. Year of development: 2009. Number of tools available: >400. Supported operating system: Windows, Linux, Mac OS X. Update: v. 3.4.0, release from 01.2017. Programming language: Python, JavaScript. There is no Ukrainian (Russian) translation of supporting documentation.
4. The Saga. Purpose and Functionality: educational and research goals, geospatial analysis, cartography, support for raster, vector, satellite data. Year of development: 1990. Number of tools available: >600. Supported operating system: Windows, Linux, Mac OS X. Update: v. 7.6.1, release dated 02.2020. Programming language: C++, Python. There is no Ukrainian (Russian) translation of supporting documentation.
5. GvSiG. Purpose and Functionality: 3D visualization, real-time geospatial analysis, cartography, support for raster, vector, satellite data. Year of development: 2004. Number of tools available: >200. Supported operating system: Windows, Linux, Mac OS X. Update: v. 2.5, release from 11.2019. Programming language: Java. There is no Ukrainian (Russian) translation of supporting documentation.

The given open GISs do not have high hardware requirements and support ability to work on different operating systems except ILWIS, which runs exclusively on Windows. Considered open desktop GIS are created in different programming languages, and in their current versions support writing scripts in most available languages (Python, C, C++, etc.).

We will emphasize such important aspect of mastering geoinformation systems as working with geospatial databases. Most open GIS support reading and writing (editing) features of geographical and spatial data as well as temporal characteristics and attributes. For example, GRASS GIS and QGIS support PostGIS, and uDIG and gvSiG also work with Oracle. The current version of Saga GIS implements model of exporting/importing data to/from PostgreSQL, MySQL [46].

We believe that lack of available documentation in Ukrainian or at least Russian languages is holding factor to active use of described open GIS in the educational process. All available documentation, libraries, tools are described in detail on the

developers' websites in English. Analysis of interface part of open GIS showed that they are inferior to convenience and intuitiveness of ArcGis and MapInfo, but not all. Practice shows that open GIS such as uDIG, QGIS, and Whitebox GAT are accessible and understandable to students. It is more difficult to master the GRASS and Saga GIS tools and functionality, since the constant execution of procedures and the challenge of operating teams requires students to have initial skills and understanding of the principles of these GIS. Therefore, these GIS can be used in teaching of students and postgraduates.

4.3 Computer modeling in monitoring of environment

In order to demonstrate examples of GIS work it is necessary to prepare a number of monitoring data. It is possible to monitor the environment, simulate and display pollution levels, predict the occurrence of environmental emergencies, identify areas with the highest concentrations and areas of risk to public health, inform the population about the current environmental status of the environment, the dynamics of its environment, sources of pollution, disposal of waste, the nature of the impact of environmental factors on human health, providing free access to environmental information [12] using GIS in environmental monitoring tasks.

Monitoring data should be presented appropriately. Only a narrow group of experts in environmental quality monitoring or modeling assessments are able to use raw data, not decision makers or the general public. Interpretation of spatiotemporal variability of pollution is greatly facilitated if conventional digital data are presented in the form of graphs, drawings and maps [12]. Use of geographical maps makes presentation of more complex comparative characteristics of pollution easier. Pollution concentrations for different observation points can be demonstrated in a simple way.

Today following domestic and foreign information software-modeling systems are used to solve problems of environmental monitoring of the atmospheric surface layer, namely: EOL-2000 [h], "Povitrya", ARM EKO, "Ekotrans", EcoStat, "ЭПА-Воздух", "EPK ROSA", UPRZA "Ekoloh", "Mahystral-horod 2.3", "HYS – atmosphere", "RADExpert", RODOS, RECISS, NOSTRADAMUS, ARGOS, JSPEEDI, NARAC, MEPAS and others.

Important practical aspect is use of information software developed by the authors for the tasks of monitoring and control of the environmental status of urban areas - the AISEEM system by future specialists.

The AISEEM system includes unit of statistical analysis and preliminary assessment of technogenic atmospheric loads; mathematical modeling and forecasting unit of atmospheric pollution and risks for the population; block of visualization and construction of ecological maps. This system has an electronic map unit, number of tools for working with them and certain characteristics of GIS. So, it can be considered as specialized GIS.

The developed information software is aimed to solve many scientific and practical problems of environment monitoring of ground atmosphere layer described in the publication [12].

Currently, AISEEM is implemented in various organizations, enterprises and several

higher education institutions.

Let's consider, for example, the application of AISEEM to simulate various tasks that may arise in the work of future specialists in the specialties: 101 "Ecology", 103 "Earth Sciences", 122 "Computer Science", 183 "Environmental Technology".

Task 1. Modeling of technogenic loads on the atmosphere during long period of time.

Construction of adequate mathematical model for scattering of pollutants in the atmosphere is based on the solution of complete equation of turbulent diffusion. Today only solutions of simplified variants of this equation are known. It also does not allow to obtain sufficient accuracy of modeling of technogenic load from emissions of stationary sources of pollution taking into account various peculiarities of meteorological characteristics, emission parameters and mode of operation of a potentially dangerous object.

The authors of this paper constructed an adequate mathematical model of atmospheric pollution from stationary source emissions based on solution of turbulent diffusion equation in general form [43]. The model adequacy was verified by comparing modeling results of atmospheric air pollution by emissions from the respective stationary sources of pollution with data of full-scale measurements of the concentration of certain pollutants at the relevant points of influence area of technogenic object. Data from the emissions of the largest stationary technogenic emission sources in Kyiv and the data of concentrations of all substances monitored at the stationary observation posts in Kyiv for 2017 were used for the model validation. Values of pollutants concentrations were obtained by official request from Central Geophysical Observatory named after Boris Sreznevsky. The test results showed that the simulation error does not exceed 15%, which is absolutely acceptable for this class of problems.

Figure 1 illustrates examples of modeling of concentration distributions of atmospheric air concentrations near the Earth's surface as a result of emissions of relevant man-made stationary sources using the AISEEM system.

Task 2. Assessment of human health risks by technogenic atmospheric factors.

The developed software helps to move from the spatial distribution of technogenic load levels to the distribution of individual risks for the population of urban areas (risk maps). Risk assessments complete the modeling process of technogenic loads impact on the city population and determine the criteria for managerial decision-making. According to the methodological recommendations for the risks assessment to public health, risks analysis of atmospheric air pollution includes four stages: danger identification of individual influence factors; assessment of effect degree of these factors; establishment of dose-concentration-effect relationship; characterization of risks to public health. These steps are reflected in detail in the authors' proposed expert-analytical approach to risk assessment based on environmental monitoring data [30].

The interpolation was performed on the multiplicity principle of exceeding maximum permissible concentrations. The resulting risk values are depicted on the maps as contours of different shades, colored according to the values of the scale shown at the bottom left of each figure.



Fig. 1. Map of sulfur dioxide emissions distribution from the largest Kyiv's enterprises (2019)

Algorithms and software were developed to implement possible scenarios for monitoring data analysis from different sources, taking into account expert assessments of the tolerability of different levels of health risks for different categories of population based on the proposed approach.

AISEEM calculates: the risk of chronic intoxication (RCI), the risk of immediate toxic effects (RITE), the characterization of the risk of developing non-carcinogenic effects, the characterization of the risk of developing non-carcinogenic effects due to the combined exposure of chemicals and carcinogenic risk.

Figure 2 shows examples of RCI and RITE integrated maps due to Kyiv air pollution in 2019, constructed using the weighted distance interpolation method.

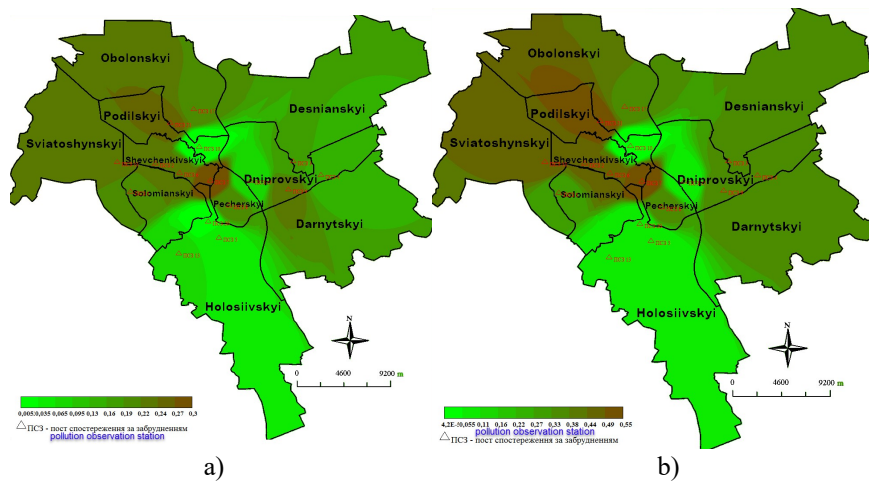


Fig. 2. RCI (a) and RITE (b) as a result of air pollution in Kyiv in January-December 2019

5 Conclusions

Nowadays GIS-based information materials as part of geoinformation knowledge and skills become very popular. However, the future specialists training in new technological era remains at a level that does not fully meet the needs of manufacture, science and management [14]. It should be noted that not all educational programs of higher education institutions and scientific institutions providing training in the specialties: 101 “Ecology”, 103 “Earth Sciences”, 122 “Computer Sciences”, 183 “Environmental protection technologies” include GIS as a discipline. This is a major drawback due to the article’s authors opinion as far as the ability to use GIS is interdisciplinary. It develops knowledge and skills in computer modeling of various processes that may arise in the future professional activity.

Advantages of open GIS using in higher education and scientific institutions include following: cost savings (no need to acquire licenses); functionality of open GIS is not inferior to its commercial counterparts; most open GISs do not have high hardware requirements and support the ability to work across different operating systems; expanding the competences of undergraduate and graduate students to use different GISs and combining them to solve practical problems.

GIS for educational process is defined after the analysis of scientific publications and curricula of various Ukrainian higher education institutions. It significantly narrows the knowledge and skills of students and postgraduates particularly in computer modeling due to the authors’ opinion. It was determined that the process of future specialists training in the fields of “Ecology”, “Earth Sciences”, “Computer Sciences” and “Environmental Technology” should be based on the use of powerful scientific and methodological training base using modern achievements in the information technology field. Used software choice in the educational process should be made not based on the subjective preferences of the teacher, but with the need for students and postgraduates to understand the process of GIS functioning in general, to develop a system of their thinking, ability to choose the best tool for solving a specific application problem. In this context use of open and specialized GIS helps students and postgraduates to understand the “logic” and “mechanism” of problem solving and to move away from the routine implementation of the learned sequence of actions. Open and specialized GIS give an additional opportunity for enrichment of educational courses with didactic material in higher education institutions and scientific institutions. Students and postgraduates obtain opportunity to work with different software solutions, compare them, choose to solve specific problem by the most optimal tools based on experience.

There are following main criteria for selection of open and specialized GIS that are appropriate to use to prepare students and postgraduates: their openness, functionality and suitability for use in higher education and scientific institutions of Ukraine.

Comparative analysis of the most common open GIS in the world was performed. It is recommended for students to use proprietary (ArcGis, MapInfo) and open GIS (uDIG, QGIS, Whitebox GAT). It is possible to use open GIS (uDIG, QGIS, Whitebox GAT) and specialized (Modular GIS Environment, GEO + CAD, GeoniCS, AISEEM) to teach students and postgraduates.

Therefore, advantages of open GIS using for students and postgraduates are following:

1. To create their own GIS prototypes (open license, wide library of ready-made tools, unrestricted integration into other systems, etc.);
2. To use Open Desktop GIS in different programming languages and to support scripting in most languages available to students;
3. To create facilitating of systematic understanding of work process with GIS by students and postgraduates, processing of geospatial data regardless of selected software type;
4. To modernize the educational process.

Based on our own experience we recommend to develop open and specialized GIS skills to address current environmental and socio-environmental challenges to educate students and postgraduates in computer modeling.

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Fluid Flow Modelling in Houdini

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Abstract. The modern educational environment in the field of physics and information technology ensures the widespread use of visualization software for successful and deep memorization of material. There are many software for creating graphic objects for presentations and demonstrations, the most popular of which were analyzed. The work is devoted to the visualization of liquids with different viscosity parameters. The article describes the development of a fluid model in the form of a particle stream. The proposed methodology involves using the Houdini application to create interactive models. The developed model can be used in the educational process in the field of information technology.

Keywords: Fluid Flow, Modelling, Houdini.

1 Introduction

Computer graphics today is one of the main directions of information technologies, that develops most stormily. By means of computer graphics it is possible to do visible or visualize such phenomena and processes that cannot be seen in reality, it is possible to create evident character of that in actual fact has (for example, effects of theory of relativity, conformity to law of numerical rows and others like that) unobvious [1; 9].

Scientific visualization that sometimes is briefly named by SciVis is graphic representation of data as to the means for a study and understanding of data. Sometimes such method is named the visual analysis of data. It allows to the researcher to get an idea about the system that is studied, before by impossible methods. Scientific visualization differs from graphic representation. Graphic presentation is created first of all for an information and results transfer by methods that it easily to understand [8]. In scientific visualization prevails aspiration to understand data. However often both methods combine.

In terms of calculations, SciVis is a part of the visualization which includes the research in computer graphics, image processing, high-efficiency calculations and others. SciVis tools can also be used to game design, computer animation, multimedia presentations etc. [5; 6]

2 Literature review

Programming tools that allow to create 3D graphic arts, design the virtual reality objects and create the simulated images are very diverse. Firstly, a comparative analysis of the platforms for the creation of AR was carried out. The most popular tools – Autodesk 3ds Max, Autodesk Maya, Blender 2.8 and Houdini – were analyzed (Table 1).

Table 1. Comparison of modeling tools

Modeling tools	Autodesk 3ds Max	Autodesk Maya	Blender 2.8	Houdini
<i>Developer</i>	Autodesk	Autodesk	Blender Foundation	Side Effects Software
<i>Operating system</i>	Windows	Windows, macOS, Linux	Windows, macOS, Linux, Amiga OS, Haiku, Morph OS	Windows, macOS, Linux
<i>Programming languages</i>	C, C#	C, Maya Embedded Language, Python, C#	Python	C
<i>Features</i>	3D modeling, Animation, Rendering software for games, Design visualization	Texturing, 3D Sculpting, Keyframe animation	Procedural Texturing, Scripting, HD-Rendering, Animations, Texturing, Rendering with graphics card, 3D Sculpting, Portable, Customizable, Video overlay, Realistic viewport, Motion tracking, Parametric Modeling, 3d sketching, Real time rendering, Texture painting, Lightweight, Physically-Based Rendering, Compositor, Keyframe animation	Modeling, Terrain, Character, Animation, Solaris: Layout Tools, Solaris: Lookdev & Lighting, Mantra/Karma Rendering, Compositing, Volume, PDG Tasks, Pyro FX, Fluids, Rigid Bodies, Particles, Crowds, VELLUM Cloth, Wire Dynamics
<i>Model of pricing</i>	Subscription	Subscription	Free, Open source	Commercial, free version for students, artists and hobbyists

Autodesk 3ds Max [3] – professional software for 3D modelling, animation and visualization, which is actively used by game designers. 3ds Max allows to create massive worlds in games, visualize high-quality architectural renderings, model finely detailed interiors and objects, and bring characters and features to life with animation and VFX.

The hundreds of 3ds Max Access plugins uses both direct manipulations and methods of procedural design, and the enormous library of industry leading 3rd-party plugins highly facilitates a design process.

3ds Max offers the professional set of tools. Nevertheless, students can get software free of charge, and a trial version is also accessible in during 30 days.

Autodesk Maya is the 3D graphic arts editor, accessible on Windows, macOS and Linux. Maya gives an industrial power by a concurrent price. Maya is perfect for design, texturizing, illumination and rendering: a large set of functions includes the manipulations particles, hair, fabric, solids, as well as fluid simulations and animations.

Today, Maya is one of the best 3D toolkits at the world market.

Blender 2.8 is a public domain open source computer graphics software of professional functionality. Blender is best in design, texturizing, animation and visualization. The long-awaited version 2.8 provides a modern intuitive interface, interactive real-time reflection with an enormous amount of corrections and new features [2].

Previous Blender versions have often been criticized due to non-friendly to beginners. Especially dissatisfied there were those who switched from other 3D packages (3ds Max, Maya etc.), because the Blender' design principles and hotkeys don't comply with the industrial standards and user expectations.

SideFX Houdini is a professional programmable package to make a 3D graphic art.

Houdini is rather a visual programming environment than classical 3D CAD as mentioned above. Houdini provides to the digital artists a power, flexible, and controlled node-based procedural environment with a lot of industrial-grade visual effects to create high-quality physical 3D animations (Fig. 1). Like Maya and Blender, this powerful and non-standard workflow can be tricky for beginners, so Houdini also provides a set of traditional visual tools [4].

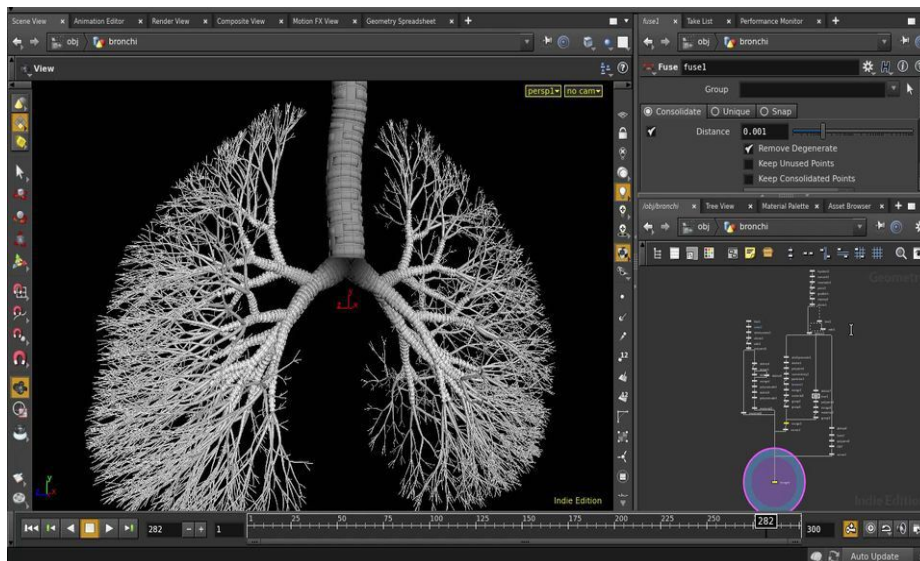


Fig. 1. Houdini FX interface

SideFX offers Houdini Apprentice, a free version of Houdini FX, that students, digital artists and amateurs can use for the personal noncommercial projects. Houdini

Apprentice gives access to almost of all Houdini FX features. The full-featured Houdini Indie is an affordable commercial option for small studios.

Houdini is mainly used for realistic physical simulations (e.g. particles dynamics), procedural modeling, animation, effects, rendering, and compositing.

To work with Houdini, you need to understand the basic principles of procedural modeling – a number of computer graphics methods for creating 3D models and textures. Procedural modeling is often used to create 3D models of complex shapes (plants, architecture building).

With the features provided by Houdini, you can build models, objects, simulations and customize them, and test their performance by running and testing simulations directly in the Houdini editor.

3 Results

We made the simulation of liquid streams (fluid flows) in Houdini. First you had to create an object that will be the source of stream. We chose a sphere primitive and added node transforms that allow you to change such sphere parameters as size and position (Fig. 2).

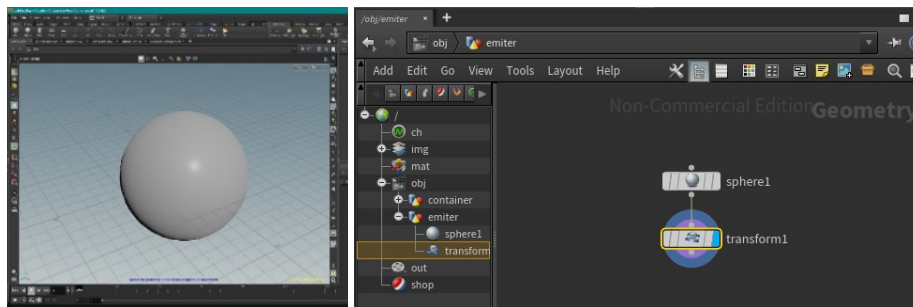


Fig. 2. Sphere and its node transform

In order to visualize how a liquid with different viscosities will flow down over surfaces, it is necessary to add another object that will simulate such a surface (Fig. 3).

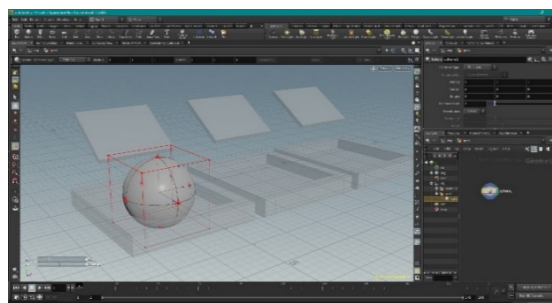


Fig. 3. Object with inclined surface and container

Then we changed the size and position of sphere by node transforms so that the sphere is above an inclined surface (Fig. 4).

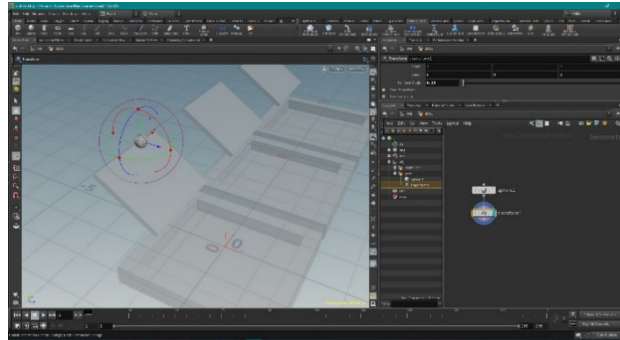


Fig. 4. Placing a sphere above the surface

To add to the sphere properties a source of the node particles, which will simulate the liquid stream, we used flippers nodes and DOP Network (Fig. 5).

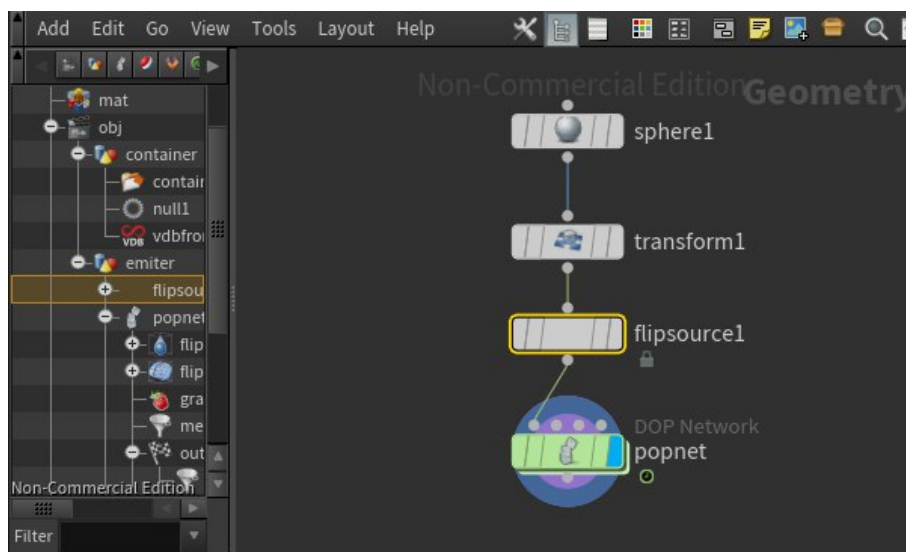


Fig. 5. flippers nodes and DOP Network

The DOP Network node contains another network of nodes (flipsolver), which is responsible for creating particles (Fig. 6).

After connecting the flippersolver network to the sphere, you can see a cloud of particles formed around the sphere only (Fig. 7). In order to imitate the fluid flow behavior, it is necessary to connect the flippersolver network to the gravity node. This will cause particles to fall vertically down (Fig. 8 a). Starting the simulation, you can see that particles behavior will be similar to liquid stream behavior (Fig. 8 b).

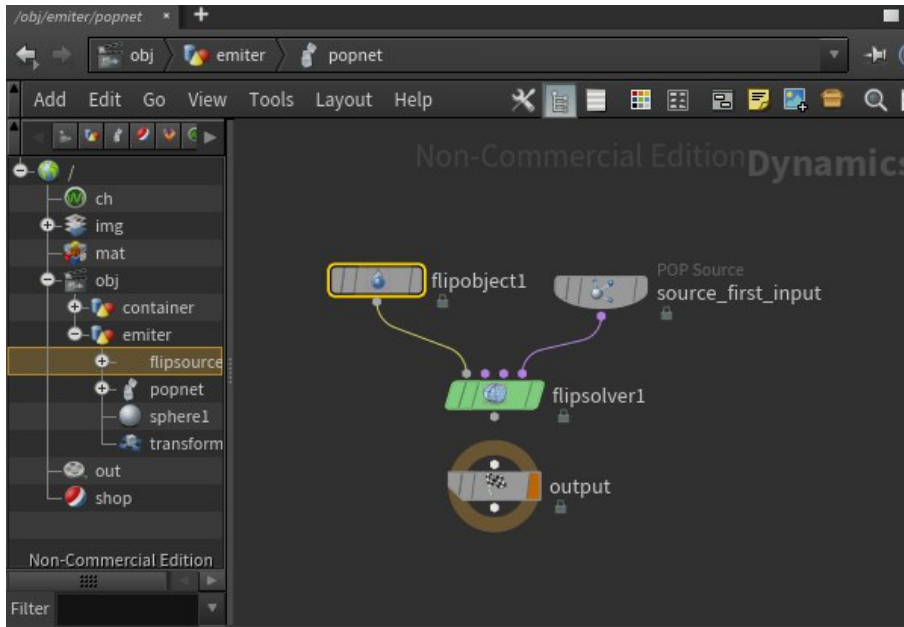


Fig. 6. flipsolver network

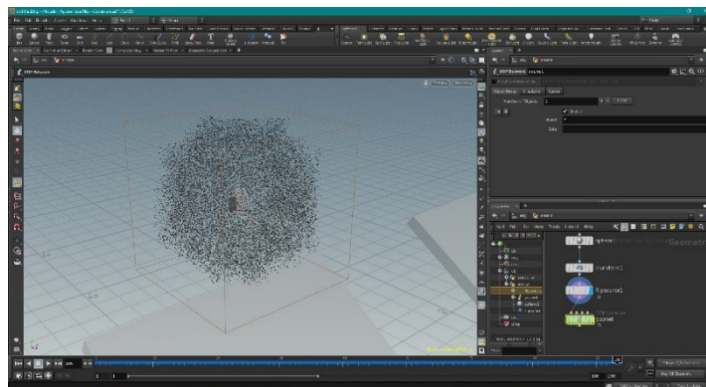


Fig. 7. The result of the flipsolver network action to the sphere

But now the particles only fall down within a given area and do not interact with a surface that was added before anyway. To enable the fluid-surface interaction, it is necessary to add a static object to the flipsolver network, namely staticobject and staticsolver nodes (Fig. 9).

Starting new simulation, you can see the physically correct fall of the particles, and how they flow from an inclined surface into the container (Fig. 10). At this stage, the particle stream simulates a liquid without viscosity, temperature or density. You can add these properties in the flipsolver network settings window. We set the Viscosity parameter to 100 (Fig. 11).

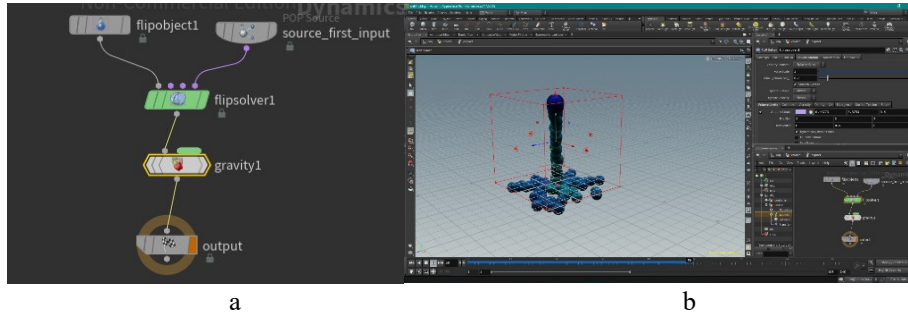


Fig. 8. Gravity node (a) and its action (b)

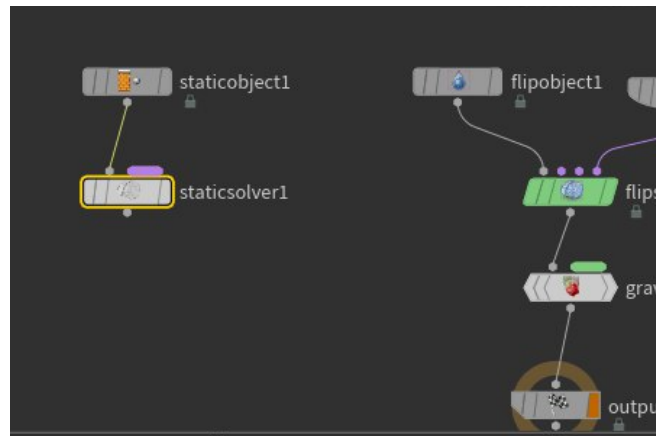


Fig. 9. staticobject and staticsolver nodes

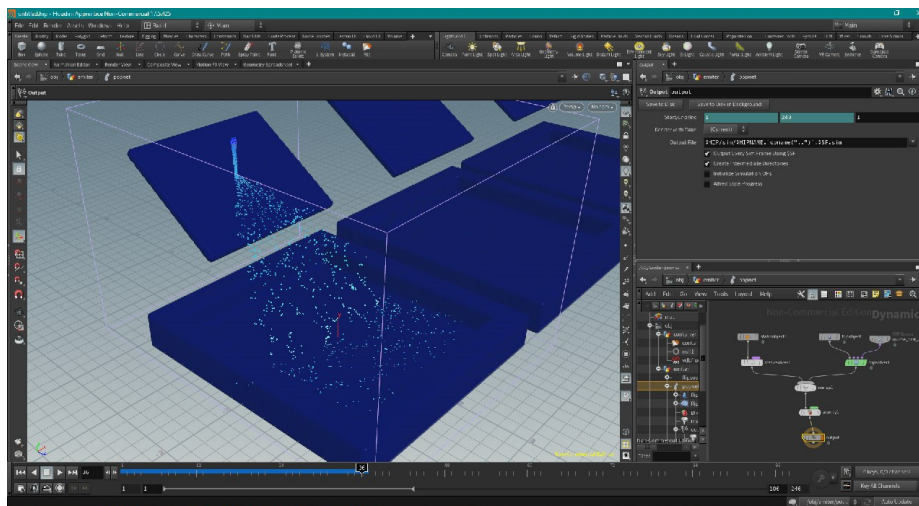


Fig. 10. Particle flow simulation

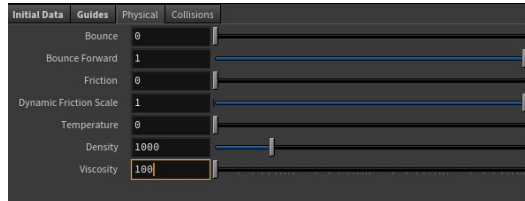


Fig. 11. Fluid physical parameter settings window

Running simulation again, you can see how the Viscosity parameter affects the fluid flow behavior. The stream flows from the surface much slower and looks like a viscous substance such as honey (Fig. 12).

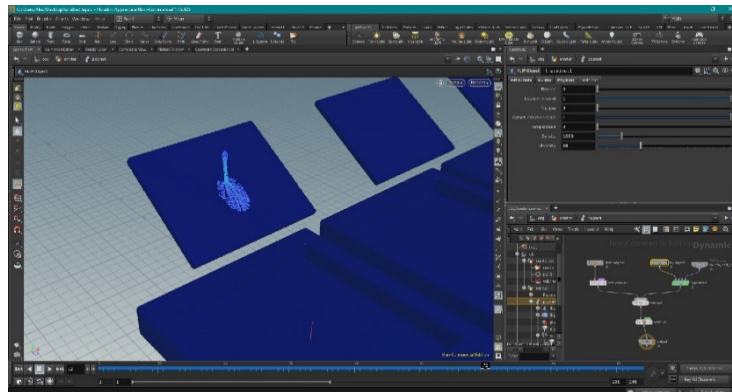


Fig. 12. A simulation of particles stream with the non-zero viscosity parameter

The behavior of liquids with different viscosity is shown on Figure 13.

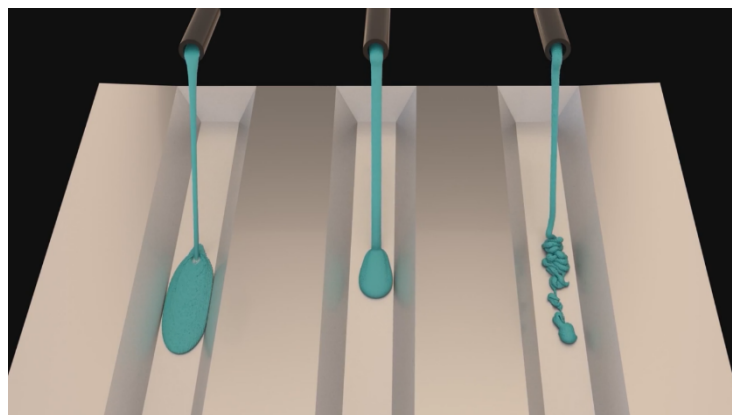


Fig. 13. Modelling liquids with different viscosity

4 Conclusions

1. The use of programmable environments like Houdine to create physically correct 3D models has a deep impact on both the science education and CS education. This makes learning visual and fun. Using the proposed software and the implemented models to make the simulated animations is more effective than using traditional experiments and pre-recorded video.
2. Learning using interactive 3D models in a mixed environment can be useful for a deeper understanding of the simulated processes, so our further research will be on the VR/AR using to facilitate training the bachelors majoring in CS.

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Interactive Augmented Reality Technologies for Model Visualization in the School Textbook

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Abstract. AR-technologies can be widely used in the educational process using ICT. Especially valuable is the use of AR-based applications for the visualization of illustrations of models of objects and processes in school books. The use of electronic educational resources using AR-technologies can improve the quality of students' knowledge, as well as provide teachers with a wide range of new opportunities.

Using AR technology allows you to design and create effective learning resources. This develops students' creative thinking and increases their motivation to learn.

In this paper, we consider a model of a learning system using augmented reality technologies for visualizing illustrations in school textbooks.

A survey of secondary school teachers showed the possibility, interest and effectiveness of using e-learning tools based on AR technology. Pupils can use this electronic resource both in class at school and at home during independent study.

Students of Kherson State University, interviewed in the STEM education system, showed a willingness to work with augmented reality technologies.

To assess the prospects of using AR-based applications in the educational process, an expert method was used. Experts evaluated the prospects of using AR technology to visualize 2D and 3D models of educational objects. For evaluation, a five-point Likert system was chosen.

The developed model can be used as a means to create the basis for future research, development and dissemination in the system of educational institutions. The proposed model of the learning system was tested in the classrooms of students in the learning process at STEM.

Keywords: Augmented reality, ICT, mobile application, visualization, school textbook.

1 Introduction

New information technologies are widely used in the development and use of electronic educational resources (ESM). Virtual and augmented reality (VR, AR) technologies are actively used to improve teaching methods using information technology.

Augmented reality (AR) is a type of virtual reality technology that blends what the user sees in their real surroundings with digital content generated by computer software. The additional software-generated images with the virtual scene typically enhance how the real surroundings look in some way. AR systems layer virtual information over a camera live feed into a headset or smart-glasses or through a mobile device giving the user the ability to view three-dimensional images [1]. In other words, AR is an interactive experience of the real world environment in which objects located in the real world are “augmented” by computer-generated perceptual information, sometimes through a variety of sensory modalities, including visual, auditory, tactile, somatosensory and olfactory. AR objects can be interactive, dynamic, or static. Modern teaching methods are aimed at improving the quality of students' knowledge. This can be achieved by introducing new approaches into the educational process and using new technologies. Interactive teaching methods using distance technologies have a positive impact on the quality of students' training, the development of their professional competencies necessary for successful competition in the global labor market [2]. Augmented reality allows you to study the work of various dynamic and static systems, expanding the boundaries of reality, which in turn helps to increase students' interest in the subject of the study area, better learning new information. The difference between AR and VR is a systematic approach to technology and the use of different technical equipment. AR complements the existing one, VR with the help of virtual reality glasses completely changes our environment (only at the visual level, not physical).

The relevance of using AR in high and secondary school is significant when studying a wide range of disciplines for

- visualization of models of systems and processes,
- detailing the presentation of properties of complex objects,
- visualization of abstract objects,
- conducting virtual excursions and travels, etc.

The subject of the study is the software and hardware of the training system using interactive augmented reality technologies.

The purpose of this work is to design a system and develop software for visualizing processes and models of objects in a school textbook using interactive augmented reality technologies.

We list a number of works that summarize the experience in the development and use of training tools using AR in educational institutions of Ukraine and abroad.

The authors of the Institute of Information Technologies and Learning Tools of NAES of Ukraine” in their article describe the main problems of modern education in higher educational institutions of Ukraine and their solution using AR [3].

A detailed description of tools for developing applications using AR can be found in the article [4]. For ourselves, we have identified such development tools as Unity and Vuforia. Unity is one of the most common development environments for the visualization and interaction of 3D objects. You can expand the functionality using the Asset Store library. There are a large number of different plugins and extensions in the Asset Store. Vuforia is a platform that allows you to install the application on a mobile device with a camera to "see" and recognize various objects, images, texts and markers

located on them. Vuforia is supported by mobile devices running Android 4.0.3 and iOS 7 and above.

Tony Liao identifies key themes and areas of focus for AR technology use: AR users/nonusers, AR devices, AR content, and AR industry. By organizing these lines of research, manuscript serves as a call for specific future areas of research, suggests new approaches that researchers could take to explore interrelationships between these areas, and advocates for the necessity of research that examines different levels (micro/meso/macro) of analysis within AR [5].

The article [6] explores some key features of virtual reality (VR), augmented reality (AR), and merged reality (MR) as well as the differences between them. The aspects of possible usage of reality technologies in the contemporary world are considered. The attachments to augmented and virtual realities that exist and are used in modern educational process are reviewed. The importance of forming of the students' STEM competence and the creation of the innovated STEM-education model are indicated. The article denotes the need of special technical equipment and special virtual laboratory for the implementation of virtual and augmented realities' systems into the modern educational process.

In the article [7], by combining AR with elementary learning materials, the researchers create a set of Ubiquitous Augmented Reality Digital Learning System and design Augmented Reality 3D Digital Media teaching materials based on the content of textbooks. The researchers adopt Triangulation, including System Usability Scale, NASA-TLX and qualitative research methodologies, to examine Usability Evaluation of Ubiquitous Augmented Reality E-Learning System.

Article [8] describes the experience of using VR and AR-based applications in the education system of the STEM school at Kherson State University (KSU).

The work [9] discusses the evolution and changes over the time of the use of VR and AR in the main areas of application with an emphasis on the future expected VR's capacities, increases and challenges.

The work [10] discusses the questions about hardware difficulties, lack of real uses so far and marketing challenges of using software with AR.

Article [11] describes a typical AR system with software and hardware architecture based on modern technological advances. The use of AR in various areas, especially in the field of the military system, equipment support, and simulation training, has been investigated.

A smartphone can be used as a mobile device for the tasks of visualizing objects and processes in a school textbook. Use Case Diagram (Diagram 1) shows the options for user actions with a smartphone [12]. Aspects of AR-based applications programming technology were kindly provided by Nicolò Carpignoli [13].

Diagram 1 contains the following main elements.

1. Scan QR Code can be a marker of the first interaction of the user and the system. It is assumed that each textbook has its own QR Code. This user case is called when the user wants to scan the QR code on the front of the AR popup book.

2. Scan AR Markers: This interaction is called when the user wants to scan the various AR markers in the AR popup book after successfully scanning the QR code of the AR popup book.
3. View Overlaid Information: This interaction is called when the user wants to view information overlaid after successfully scanning the AR markers.
4. View Help: This interaction is called when the user wants to view help information. It is a simple call that terminates after the information is displayed.
5. Quit: This interaction is the link to the application endpoint. All calls to this use case represent a request to terminate the application.

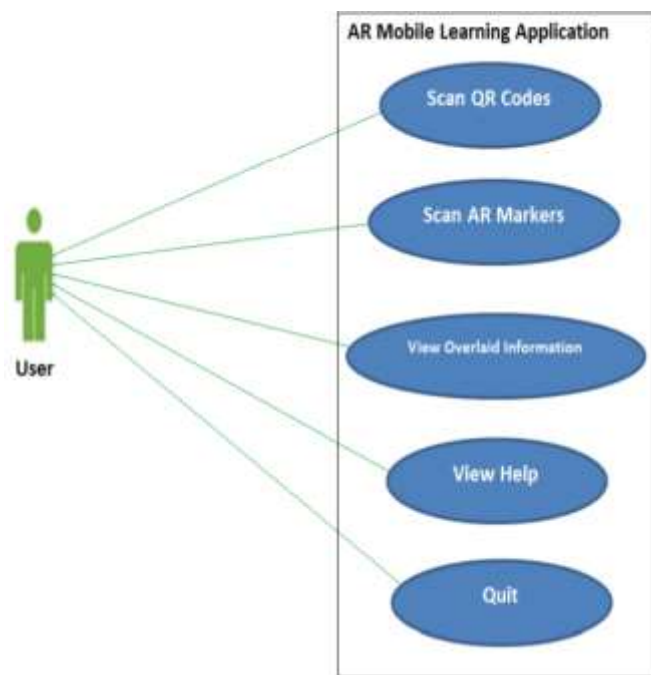


Diagram 1. Use Case Diagram.

When developing software using VR and AR-based applications, the platforms on which computer games are created are usually used (Unity [14], Unreal Engine [15], etc.). At the same time, such tools as Steam VR [16], Google VR [17], Oculus [18], Windows Mixed Reality [19], Google ARCore [20], Apple ARkit [21], Google Tango [22], Vuforia [23] and others can be used.

Consider several examples of the use of these programs and technologies:

Authors of article [24] presents the experience of developing 2D and 3D virtual laboratories based on the cross-platform game engine Unity for studying physical phenomena and processes.

Expeditions [25] is an application developed by Google. Using Google Cardboard, you can go on an archaeological expedition and see the excavations, take an underwater trip along the ocean floor or swim with sharks. This application is already used in their lessons by many teachers around the world.

The mobile application "Mars is a Real Place" was developed using Oculus technology [26]. The musical slide show consists of stereoscopic 3D photographs of Mars. 80 fascinating high-resolution 3D images are presented, carefully thought out for easy viewing. Images are a combination of views from the orbit of Mars and panoramas taken on the surface.

Sky Map [27] is an Android planetarium software application. Sky Map was designed and developed by a group of Google engineers in Pittsburgh, Pennsylvania. This application used to identify stars, planets, nebulae and more.

2 Description of the learning system model using AR Visualization in a Schoolbook

First of all, let's consider the definitions of the basic concepts. By a *learning system using AR*, we mean a hardware and software environment in which the states and processes of functioning of complex systems are visualized, and aimed at improving the efficiency of student learning. Interactive technology enables the information and communication training system to variably respond to user actions in an active mode. The main goal of such a learning model is the active involvement of students in the educational process.

The term "*trigger image*" will be understood as any image on the pages of an electronic textbook that has the properties of a trigger for a mobile application and allows displaying elements of augmented reality on the device.

A *virtual object* is a 3D object that is displayed and used in a mobile application for demonstration in AR.

Consider a learning system using interactive augmented reality technologies, consisting of a regular paper school textbook containing textual information of a specific subject area, which is illustrated by drawings or photographs.

A model of this system is shown in Fig. 1.

School textbook is the main learning resource in the learning system using AR. Images in the school textbook serve as a trigger for visualizing models of existing objects that the user sees on the smartphone screen as a result of the application. An electronic book may also be used, which is the publication of a book in digital form, consisting of text, images, or both, which can be read on a flat display of computers or other electronic devices.

Smartphone is a mobile device with the necessary OS parameters (version of Android or IOS, camera availability, Internet access) and with the installed AR application.

Database is used for external storage of training resources and is an important element of the training system. All mobile devices have memory limitations, on the basis of this, a system should be developed, part of the resources of which will be stored in the database.

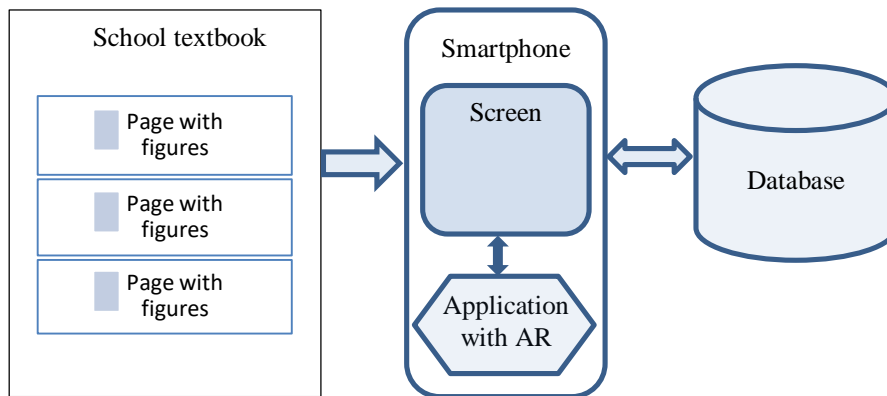


Fig. 1. Model of a learning system using AR.

Before creating a learning system using AR, a scenario plan is required, which should include the following components:

- name of e-learning resources;
- class e-learning resources: multimedia electronic educational resource;
- presence of interactivity and multimedia: This system contains multimedia and interactive elements - tests, videos, simulators;
- description of the user interaction with the content: User interaction is carried out through data exchange with the system server (the User can download the necessary resources and also enter data during the test);
- indication of the software required to work with the e-learning resource;
- 3D objects to create models;
- convenient user interface for using the application.

When creating an e-learning resource, the following tools are used:

- Multimedia technologies and platforms, that used to create AR applications (3ds Max, Unity 3D, C #, JavaScript, Vuforia).
- UML modeling tools (www.draw.io), when designing the program.

3 Software modeling and design

The application for learning with AR usually consists of the following components:

- “Help” (instructions for this application),
- “Exit” (exit from the application),
- “View object” (the camera screen for trigger scanning appears).
- “levels” (opens the screen to select the level of the scenario),
- “level” (opens the selected level).

The diagram of use cases for interactive training application with augmented reality is shown in Fig. 2.

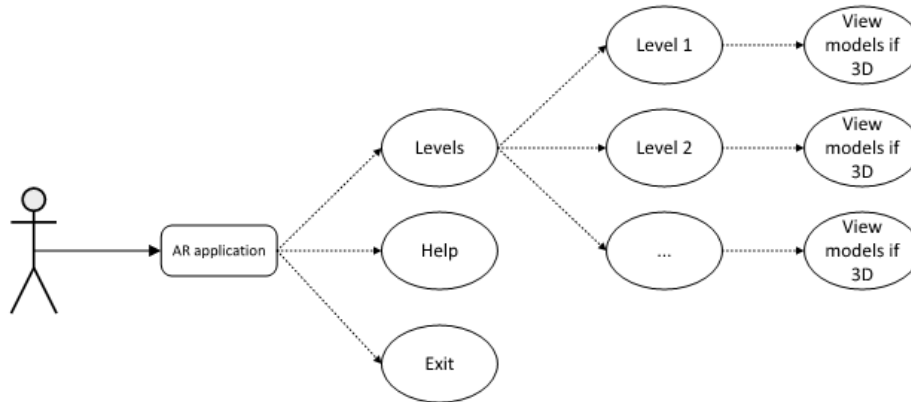


Fig. 2. Use case diagram for AR application.

The sequence of user actions when working with the application for learning augmented reality and virtual reality is shown in Fig. 3.

An example of designing classes in the development of virtual and augmented reality applications is shown in Fig.4.

To use the AR environments, the student needs to install two corresponding applications on his smartphone.

When application for AR launched, the student gets to the main menu of the program:

- by clicking on the “help” button you can find out the instructions for this application,
- by clicking on the “exit” button it will close the application,
- by clicking on the “levels” button, a screen appears to select the level of the game that corresponds to the lab number,
- by clicking on the “level 1” button, the user is inside the virtual space, organized according to the requirements put forward to conduct this virtual laboratory work.

After the camera screen appears, you must aim the camera lens on the page with the task. The program recognizes the image trigger. Each trigger is unique. He links the 3D image and page of the book with the corresponding task. As a result, a moving 3D object will appear on the screen against the background of the corresponding page of the book.

After the user opens a certain level, he gets the opportunity to study in detail all the 3D objects of the scenario in virtual reality and their interaction according to the learning objectives. Since the inclusion of a certain level of the program is in standby mode, the user can perform control and navigation actions. At the moment of performing a certain action with objects, the user in the background can see the corresponding contextual help and training information.

For a better understanding of the technical characteristics inherent in the objects used in this model, consider the description of meta-objects, objects in the real world and objects used in laboratory work.

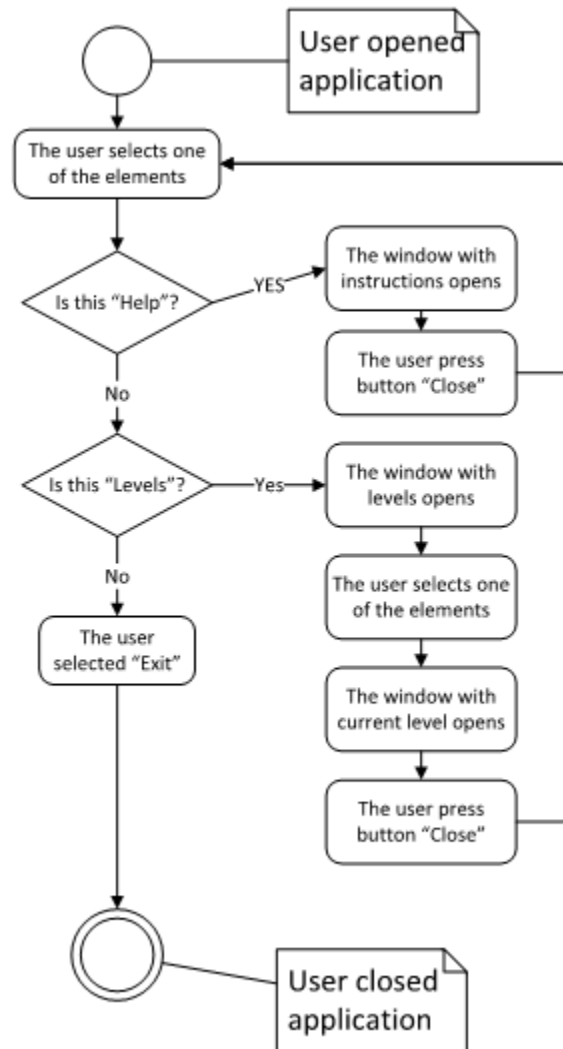


Fig. 3. Activity diagram for AR application.

Consider a model for constructing a learning system using AR (Fig. 4).

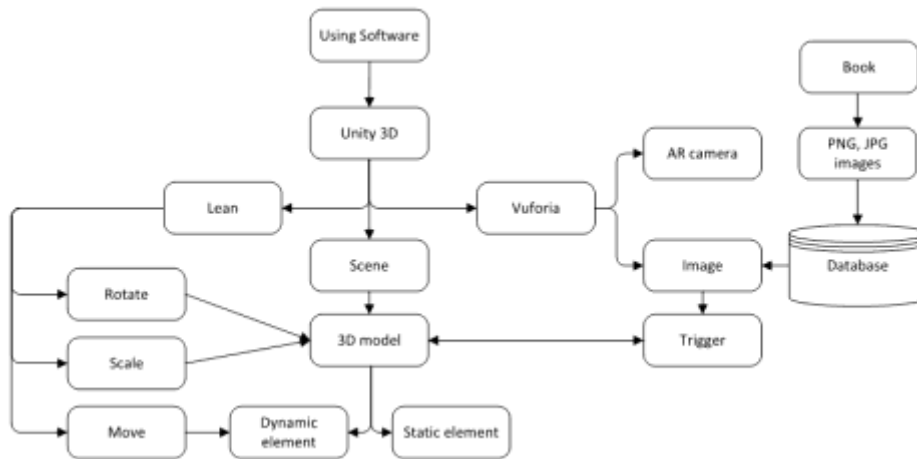


Fig. 4. Model of system

- Unity 3D allows to develop applications for Android.
 - Vuforia is an augmented reality mobile platform supported on Unity 3D.
 - AR camera initializes Image with the image that the camera transmits.
 - Image is a graphic object from the database, which is a trigger for the AR application.
 - 3D models – multimedia 3D objects in the public storage for users (Asset Store, Google search) or developed own models (3D Max).
 - Static elements – elements that the user cannot move.
 - Dynamic elements – elements that the user can move.
 - Lean is a class library of the Unity 3D platform for managing objects.
 - Rotate - rotate an object.
 - Scale - resize an object.
 - Move - move an object.
- Database – Vuforia platform database, which stores images for later use in the application.
- Book – school textbook with images that serve as triggers in an AR application.
 - PNG, JPG images – images and other multimedia resources, that are added to the database.

To use the software for its intended purpose, you must have a textbook with triggers and a smartphone with an AR application. The application will display a scene with a 3D model depending on the trigger found, each trigger has its own scene. The trigger is the image in the textbook. The camera initializes the image and displays a model that is attached to this image. Since Vuforia is supported only by mobile devices running Android 4.0.3 and iOS 7 and higher, this is a prerequisite that must be observed (Fig. 5).

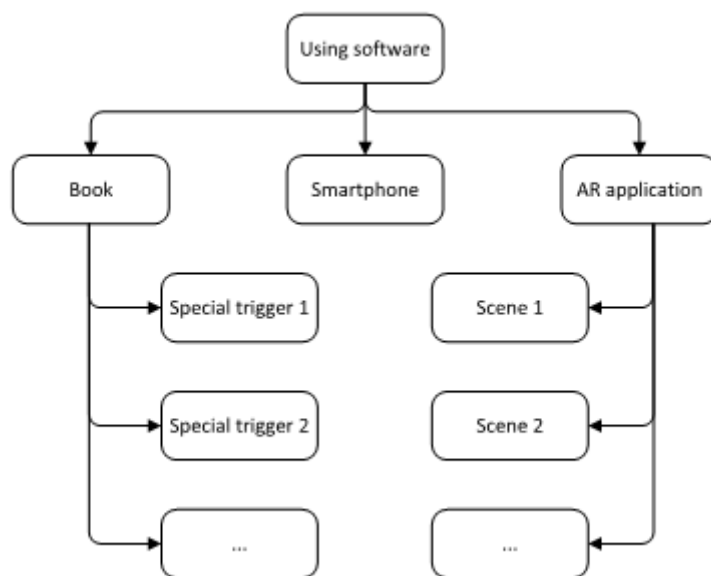


Fig. 5. Class diagram for AR application.

The interaction of objects occurs after the user presses certain control buttons that trigger a trigger set for interaction between objects.

4 An example of using a learning system using AR

We will consider in more detail the process of modeling and designing AR educational objects using the example of visualizing models of physical processes in a school physics course.

As an example, consider a school textbook in physics for grade 8 edited by V.G. Baryakhtar, S.O. Dovgy [28], topic “Thermal Conductivity”, § 2. Temperature dependence of the size of physical bodies, page 15. An example of illustration of the property of thermal conductivity of bodies is considered in the textbook (Fig. 6).



Fig. 6. Experience illustrating the property of thermal conductivity of physical bodies.

In Unity 3D, Vuforia has developed a 3D model for trigger # 1. It consists of such elements: a book, a glass, half a carrot, a metal dart, two whole carrots (these elements are static), a candle (this is a dynamic element).



Fig. 7. Visualization of the thermal conductivity of physical bodies using AR.

The user can move the candle along the diagonals x, y, z. If the candle is under the dart, after some time, due to the temperature change, the dart will change its angle of inclination, if after that the candle is removed, then the dart tilt will return to its original position due to the temperature change to the original one. This is confirmed by the laws of physics. Students can take part in this experiment themselves (Fig. 7).

Consider the following example, demonstrating the thermal conductivity of metals, paragraph 5, figure 5.1 from the school textbook [28] (Fig. 8). This figure acts as a trigger in the AR application.

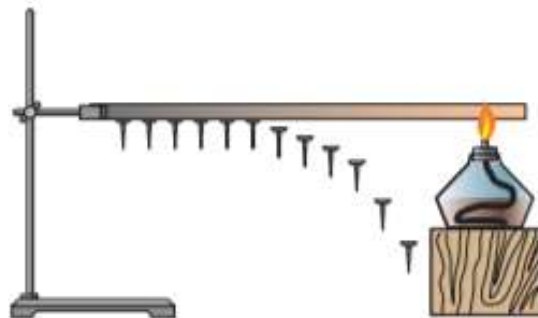


Fig. 8. This figure is a trigger in the AR application.

Unity 3D with Vuforia has developed a 3D model for the trigger Fig. 8. It consists of the following elements: a tripod, a metal dart, nails (these elements are static), a candle (this is a dynamic element).

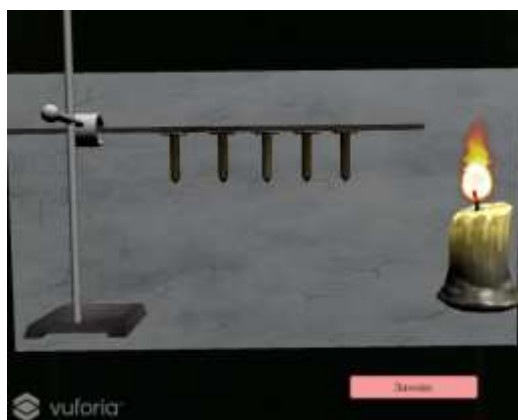


Fig. 9. Experience demonstrating the thermal conductivity of metals.

A candle is a moving object, when the fire comes in contact with a metal dart and a certain time passes (2 seconds), the nails begin to fall in turn, thus confirming the experiment (Fig. 9).

The “Repeat” button updates the application to its original characteristics. All objects fall into their original places.

5 Prospects for using AR in the educational process

We applied an expert method to assess the prospects of using AR in the educational process. 16 experienced teachers of secondary schools of Kherson were interviewed. Experts assessed the prospects for using AR technology to visualize 2D and 3D models of educational objects. For evaluation, a five-point Likert’s system was chosen. Table 1 shows the results of the evaluation of indicators.

Table 1. Expert assessment of learning resources using AR-based applications.

#	Evaluation Options	Grade
1	Compliance with the training program	3,9
2	Scientific validity of the use of educational resources	3,8
3	Compliance with a unified methodology	4,0
4	Availability of learning resource usage assessment	2,7
5	The optimality of the technological qualities of the educational resource	4,1
6	The importance of learning resource interactivity	4,3
7	Ease of use of a training resource	3,6
8	Student motivation	4,8

9	Classroom use	3,2
10	Use in independent work	4,9
11	The interest of teachers in the use of learning resource	3,7
12	I plan to use such a training resource	3,4

The results of expert's assessment showed on Diagram 2.

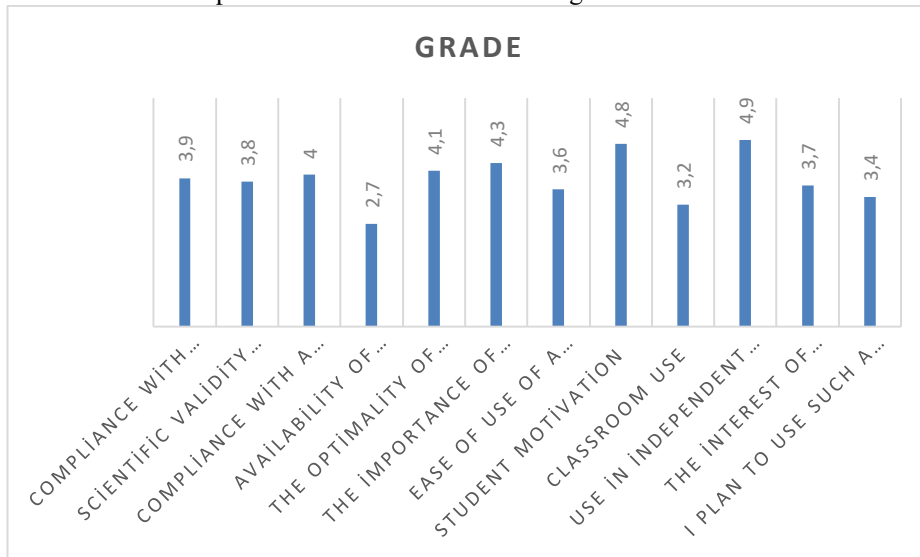


Diagram 2. Expert assessment of learning resources using AR-based applications.

An expert assessment of the quality and prospects of using training resources can be considered sufficiently reliable only if the expert evaluations are in good agreement. Therefore, statistical processing of the results of expert evaluations should include an analysis of the consensus of experts. The Concordance method is used to assess the degree of consensus of experts on options for assessment [29].

The results of the expert survey are presented in Table 2.

Table 2. Ranked expert data on the assessment of educational resources using AR-technologies.

Exp ert	Evaluation Options															
	#1	#2	#3	#4	#5	#6	#7	#8	#9	#10	#11	#12	#13	#14	#15	#16
1	11	14	2	4	5	3	6	7	9	13	15	16	12	8	10	1
2	12	14	2	9	10	5	6	4	8	11	13	15	16	3	7	1
3	10	12	3	2	6	4	5	7	8	15	14	16	11	9	13	1
4	10	7	2	4	5	3	9	6	8	13	15	16	12	11	14	1

5	10	14	2	3	12	4	5	9	8	15	13	16	7	6	11	1
6	9	10	3	2	6	4	5	8	7	15	13	16	11	12	14	1
7	12	11	2	5	4	3	7	8	10	14	15	16	13	6	9	1
8	8	13	3	2	6	9	5	4	7	16	14	15	12	10	11	1
9	11	10	4	7	8	2	3	5	6	13	9	12	15	14	16	1
10	14	2	12	7	8	13	3	4	5	6	11	10	9	16	15	1
11	15	3	11	14	7	9	5	4	2	6	10	8	13	12	16	1
12	12	13	2	8	7	3	6	4	5	11	9	10	16	14	15	1
Δ_i	30	19	-56	-37	-20	-42	-39	-34	-21	44	47	62	43	17	47	-92

Concordance coefficient W is calculated according to the formula proposed by Kendall [29]

$$W = \frac{12S}{m^2(n^3 - n)} \quad (1)$$

Here $S = \sum_{i=1}^n \Delta_i^2 = \sum_{i=1}^n \left\{ \sum_{j=1}^m x_{ij} - \frac{1}{2} m(n+1) \right\}^2$, m – number of experts, n – the number of objects of examination, x_{ij} – assessment of the i -object by j -expert. Coefficient of concordance may vary between 0 and 1. If $W = 1$, all experts gave the same evaluations for all objects, if $W = 0$, the evaluations of experts are not coordinated.

Using the formula (1) calculated coefficient $W = 0,65$ is significantly different from zero, so we can assume that among experts there is objective concordance. Given that the value of $m(n-1)W$ is distributed according to χ^2 with $(n-1)$ is the degree of freedom, then $\chi_w^2 = \frac{12S}{m \cdot n \cdot (n+1)} = 117,1$. Comparing this value with the tabulated

value χ_T^2 for $n-1 = 15$ degree of freedom and significance level $\alpha = 0,01$, we find $\chi_w^2 = 117,1 > \chi_T^2 = 30,578$. Therefore, the hypothesis of consistency of expert evaluations confirmed according to Pearson.

Thus, the results of a pedagogical experiment can be taken as a basis for the design and creation of learning resources using AR-based applications.

6 Conclusion and future work

New teaching methods using information technology are a priority today, especially when studying natural sciences in secondary school.

We described the training methodology and proposed a model of the training system using augmented reality technologies.

Currently, such training systems are in demand both in higher and secondary schools. Teachers and students can use this electronic resource both in the classroom at school and university, and at home. A survey of secondary school teachers and students of KSU showed the readiness of this category of users to work with augmented reality technologies.

The proposed model of the training system has been tested in the process of STEM education.

The developed model can be used as a means to create a basis for future research, development and dissemination in the system of educational institutions. We plan to introduce a system using virtual and augmented reality technologies in the school educational process of the STEM school of Kherson State University.

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Exploring Students' Views on ICT Skills as the Components of Journalists' Professional Competence: EDM Aspect

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Abstract. The article deals with the problem of studying students' views of the instrumental competence of journalists (ICJ) as a predictor of their professional development. The urgency of the issues under consideration is justified by the need to use the Educational Data Mining (EDM) system in higher education institutions, which is caused by the contradictions between the contemporary demands of the journalism labour market and the professional training of graduates. In this regard, the proposed study is aimed at finding possible causes for existing contradictions. Based on the results of the study of educational documents and the review of the scientific literature, authors identified the 23 information computer technologies skills that are required for journalists to perform professional tasks. The students of the first year of study ($N=207$) of three universities were asked to evaluate the importance/necessity of these ICT skills. The used in the survey questionnaire, that consist of demographic and Likert-type questions, provided an opportunity to rank the importance of assessed skills and to identify through factor analysis four significant groups of ICJ-components. They are web publishing skills, cybersecurity skills, multimedia content preparation skills, and media promotion tools. Authors compared the results of the first-year students' survey with the results of the analysis of educational programs in the speciality 061 "Journalism" (of Ukrainian universities) and identified the directions of possible improvement of the organizational component of journalistic education. The conclusions justify the using of illuminated research methodology to develop a system of analysis of educational perception data and propose prospective directions for further research.

Keywords: Journalistic Education, Professional Competence of Journalists, ICT skills, EDM.

1 Introduction

1.1 Problem statement

Some of the changes introduced in Ukrainian higher education institutions, in the particular realization of students' rights on free subjects' choice, require the careful elaboration of decision-making mechanisms, one of the benchmarks of which is objective Educational Data Mining (EDM). The possible inconsistency of higher education institutions' response speed regarding the content-methodological organization of future specialists' professional training in the speed of technology development causes the incompatibility of such training with the employers' requirements to higher education institutions graduates. Thus, according to the results of a pilot study of the state of journalistic education in Ukraine [1], which included a survey of media representatives on the quality of graduate journalists' vocational training, researchers have identified skills which are lack for graduates. Among them, in particular, the ability to find and prepare materials, sources verification, work with social networks, owning the latest formats of information submission [1, p. 45], which indicates the relevance of teaching and learning of information-technological practically oriented disciplines in the process of journalists' professional training. At the same time, the study report found that many universities teach such courses aimed at mastering students' skills of creating a competitive media product in information society environment, such as infographics, search engine optimization for online environments (SEO), blogging, data journalism, multimedia platforms, social media, convergence editing, and online editology: over 5 such courses are in 26% of higher education institutions that participated in the survey, from 3 to 5 courses are in about 53% [1, p. 19-20]. Consequently, according to the analyzed document, there is a contradiction: on the one hand – the presence in the system of journalists' professional training a block of disciplines aimed at acquiring students ICT skills required in professional activity, and on the other – lack of relevant skills in graduates.

1.2 The rationale for the relevance of the study

It can be assumed that such a situation may be conditioned due to the content of educational and professional programs, consisting of a list of general and professional disciplines, and their division into compulsory and optional ones. The block of compulsory disciplines is mainly university studios and theoretical courses. Instead, technology courses related to the use of ICT in the professional activity of media sphere professionals are being taken into blocks of optional disciplines. The students' choice of disciplines from the offered blocks, which must be done during the first years of studying at a higher education institution, influences the further formation of a professional portrait of a future journalist, in particular, determines the instrumental (practically oriented) component of professional competence of students. At the same time, this choice does not always meet journalists' professional needs. It is possible to confirm or refute the assumptions by clarifying first-year students' views about the professional needs of journalists (including the use of ICT in journalistic practice).

Student's views about necessary for professional activity realization knowledge and skills is one of the components of their personal professional theory (PPT), which to some extent defines professional behaviour and influences motivational attitudes towards acquiring new knowledge in the aspect of professional competence formation (by Harmen Schaap [2, p. 11]). Thus, defined views are a determinant for students' choice of disciplines and a predictor of formation on their basis of a certain set of special professional competences. Given this, studying students' views about future profession will help, on the one hand, to take into account their educational needs in the educational process and, on the other, to adjust them according to current labour market needs. Besides, the study of analyzed students' views is related to such typical tasks of EDM, as design and forecasting of graduates' professional competency, analysis and forecasting of students' competitiveness in the labour market, development of educational programs, disciplines and curricula following the obtained information. Therefore, relevant research can be classified as exploratory, aimed at identifying basic procedures and methods for further development of appropriate EDM algorithms for effective decision making.

The purpose of the article is to highlight the results of the analysis of views first-year students' in the speciality 061 "Journalism" about the instrumental competence of journalists (ICJ) as one of educational data components that are predictors of the professional development of higher education applicants.

The following tasks are envisaged for the realization of the purpose: (1) to reveal the content of the concept of "instrumental competence of a journalist" and to identify its components (theoretical analysis) based on studying educational documents and overview of scientific sources; (2) investigate first-year students' views about instrumental competence of a journalist; (3) analyze the results of the study in the aspect of Educational Data Mining theory (EDM).

2 Theoretical analysis

According to the Law of Ukraine "On Higher Education" [3], competence is defined as a dynamic combination of knowledge, skills, and personal qualities necessary for the successful pursuit of professional activity. Separation by authors in the structure of the journalist's professional competence of instrumental is conditioned by (1) division of knowledge into declarative (theoretical, fundamental) and procedural (practical, instrumental) [2, p. 22]; (2) features of the modern media space, an integral part of which are information and communication technologies as the main tools of journalists' professional activity. Accordingly, the instrumental competence of journalists is defined as a set of specialists' procedural knowledge about the availability and purpose of information software, technologies, equipment, Internet tools and services and the ability to use their capabilities in the process of creating and distributing media products following the demands of the labour market.

The analysis of educational documents and scientific works made it possible to find out the need to pay special attention to the development of ICJ in the process of journalists' professional training. Thus, the explanatory note to the Higher Education

Standard of Ukraine of the speciality 061 “Journalism” stated, that multimedia today is “an obvious trend of modern journalism, as well as the sphere of communication in general”, and therefore the requirements for ICT skills “apply to all journalism and publishing, as well as other types of social communication” [4, p. 10].

Article [5] states that ICT skills are key in the context of employers’ demand, and therefore providing students with the opportunity to gain a thorough ICT experience in the process of obtaining a higher education in journalism is a challenge for educators who need to respond promptly to dynamic changes in the field of profession journalists’ activity related to the development of digital technologies [5, p. 64–65].

In article [6], Andreas Veglis and Andreas Pomportis highlight the study results demonstrating the lack of journalists’ knowledge in certain ICT areas [6]. According to a survey *Journalists at Work* [7], conducted by the National Council for the Training of Journalists (UK) in 2018, 64% of surveyed journalists ($N=73$) said they needed new or additional skills to be fully effective [7, p. 60]. In particular, 46% of respondents include Media Analytics in Social media, 45% – Video editing, 37% – Photoshop-skills, 36% – Data journalism [7, p. 60–61]. This situation, according to J. Pavlik, is because the technology development is rapidly transforming journalism in 4 areas at the same time: (1) how journalists do their work; (2) news content; (3) structure or organization of newsrooms; and (4) relationships between news organizations, journalists and their numerous publications [8]. Thus, the study [7] recorded the testimonies of journalists about changes in the methods and tools of obtaining information [7, p. 7], as well as in the requirements for the qualification and professional skills of specialists – they must be multi-skilled and able to work with a wide range of media platforms [7, p. 8]. Özen Çatal analyzes technological changes in journalistic activity that lead to the profession transformation. Among them, the author identifies technologically driven changes in the workflow; changes in newsgathering practices; acceleration of content production models; convergence of applications for print, broadcast and online application [9]. In connection with the study of how Internet-journalism changes the practice and process of news production by journalists, the author concluded that the inclusion of media literacy and technological skills in the educational programs of journalists is one of the requirements of the present.

Skye Doherty [10], Cindy Royal [11] and others substantiate the advisability of introducing courses in the field of ICT for future journalists to answering the challenges of today. The relevance of this issue is proved by Bob Franklin, analyzing the intellectual rethinking of the theoretical and methodological foundations of journalism in numerous scientific publications devoted to the study of fundamental changes in the academic and scientific field of journalistic practice investigations in the digital age [12].

The scientific publications discuss the skills required for journalists to achieve professional success in today’s media environment in the context of its digitalization. Different views on this issue are analyzed, in particular, by Brian Creech and Andrew L. Mendelson [13]. Cindy Royal [11] highlights Debora Halpern Wenger and Lynn C. Owens “Help Wanted” researches, who analyzed the requirements for potential employees in employers’ advertisements and found that the third most desirable skills

after previous professional experience and strong writing in the requirements lists were Web/multimedia skills [11, p. 386].

The views of the members of the European Journalism Training Association on this issue are summarized in the Tartu Declaration [14]. This document identifies among the 10 core journalists' competencies the ability to present information in an effective journalistic form that, among other things, covers the following requirements for a journalist training: be able to use different types of story-telling techniques, present content in effective combinations of words, sounds and visuals; be able to make journalistic use of technology [14].

What are the technical skills that applicants for higher education in journalism should gain during their studies? In detail, the ICT skills required for journalists have been identified by Andreas Veglis according to the news production stages, namely Information Acquisition, Information Validation, Information Processing, and Information Presentation and Dissemination [15]. At each of these stages, journalists use appropriate ICT tools, which include software tools, Internet tools and services. The author suggested to group the skills required for this into 5 categories [15]. The first covers basic ICT skills (work with a suite of office applications and the use of basic Internet services). The second category is web publishing skills (basic knowledge of HTML and CSS and the ability to work with content management systems – CMS (WordPress, Drupal, Joomla! etc.)). The third category includes Web 2.0 skills: content creation and distribution through platforms and technologies (social networks, blogs, Wikis, social bookmarking, RSS). The fourth category of ICT skills is webcasting – creating podcasts and streams, and fifth combines the skills of data journalism, which is to process a large body of data and visualize it.

3 Research methodology

The investigation presented in this article is a part of scientific research aimed at studying of changes in the content characteristics of media specialists' professional training in higher education institutions of Ukraine, caused by the rapid development of modern Ukrainian and world media environment. Other parts related to the study of first and fourth-year students' views towards such components of the journalists' professional competence, as, in particular, the specialist's basic knowledge and skills and personal characteristics, will be covered in separate articles, allowing each of the study stages to be thoroughly considered.

3.1 Study objectives

The subject of the offered study was first-year students' views of the skills required to use ICT in journalistic practice. For research based on the study of analyzed sources, as well as the Higher Education Standard of Ukraine of the speciality 061 "Journalism" [4], Passport of the profession "Journalist of multimedia publications" [16], Journalists at Work survey [7], Model curricula for journalism education (2007) [17], and Tartu Declaration (2006, revised in 2013) [14], we selected such components of journalists'

instrumental competence (knowledge/skills related to software mastering, digital resources and technologies for creating and disseminating media content), as: ability to work with social networks; ability to write texts for mobile devices/Internet; knowledge of network security rules; ability to use social media for research; monitoring of online publications, print media and television; knowledge of dashboards, social media functionality; knowledge of Internet content legal regulation; media product promotion; knowledge of mobile journalism features; photo processing skills; ability to edit video; ability to use Photoshop, Illustrator, InDesign software; knowledge of the rules and skills of filming; knowledge of Internet theory and Internet technologies; knowledge of CMS tools (WordPress, Joomla!, etc); design and page making skills of digital media; ability to optimize content to SEO systems; knowledge of Web design basics and skills; ability to visualize data, to create Infographics; digital marketing skills; knowledge of website development tools; ability to use the data analysis software; knowledge of programming languages (HTML, CSS, etc.).

3.2 Participants

207 of first-year students of Institute of Journalism, Taras Shevchenko National University of Kyiv ($N=97$), Private Higher Education Institution “Kyiv University of Culture” ($N=84$), Department of Public Relations and Journalism, Kyiv National University of Culture and Arts ($N=26$) participated in the part of the research covered in the proposed article. All respondents study in the speciality 061 “Journalism”. The average age – 17.133 years ($SD=0.706$). 84% of the respondents are female, 16% – male. About 9% of respondents said they work in the media, with 60% of them having less than 1 year of experience.

3.3 Instrument

The main research toolkit is a questionnaire developed by the authors’ team, which contains a block of questions on the personal respondent data (age, gender, place of study, speciality, information on employment and work experience) and assessment block on the proposed scale of importance (necessity) of knowledge/skills/personal characteristics of a journalist in the professional activity (totally 78, including – 23 ICT skills). The assessment block is constructed according to the Rensis Likert method [18] – 4 scales were offered to the respondents: No matter (hardly ever required), Not very important (rarely required), Important (often required), Extremely important (necessary). Scales correspond to 4 assessment levels (three points from low to high), which allowed giving a numerical value to each characteristic – from 0 to 11 points.

3.4 Process

The survey was conducted using the online platform “Socrative” [19] – each participant received an access code to the appropriate questionnaire and completed the questionnaire in real-time using own mobile device. The average questionnaire completion time was 15.38 min.

3.5 Data Analysis

According to the survey results, a matrix of ranks was constructed, for which the average value for the aggregate of respondents' ranks was calculated. Table 1 shows the results of the rating distribution of the journalist's instrumental competence (ICJ) components of the first-year students who participated in the study.

Table 1. Components ranking of ICJ by the first-year students

Rates	ICJ Components
9.34	Ability to work with social networks
9.04	Ability to write texts for mobile devices/Internet
8.25	Knowledge of network security rules
8.21	Ability to use social media for research
8.18	Monitoring of online publications, print media and television
8.08	Knowledge of dashboards, social media functionality
7.99	Knowledge of Internet content legal regulation
7.69	Media product promotion
7.54	Knowledge of mobile journalism features
7.41	Photo processing skills
7.33	Ability to edit video
7.27	Ability to use Photoshop, Illustrator, InDesign software
7.26	Knowledge of the rules and skills of filming
7.26	Knowledge of Internet theory and Internet technologies
7.16	Knowledge of CMS tools WordPress, Joomla!, etc.
7.00	Design and page making skills of digital media
6.83	Ability to optimize content to SEO systems
6.74	Knowledge of Web design basics and skills
6.74	Ability to visualize data, create Infographics
6.66	Digital marketing skills
6.47	Knowledge of website development tools
6.11	Ability to use the data analysis software
4.91	Knowledge of programming languages

The highest rating among all the components of the instrumental competence of a journalist proposed for assessment was given to the “ability to work with social networks”. The high appreciation of this component can be explained by the fact that social networks today are the main source of information and the dominant environment of communication, which reaches a multimillion audience and has a number of advantages as a platform for journalism. Among them, in particular, are: the ability to monitor information flows on given topics and organize information; tracking the significance of publications and studying the information requests of the target

audience; prompt feedback; possibility to involve experts; use of tools to promote content and attract and expand the audience, etc.

Thus, the ability to work with social networks according to first-year students is a key skill of a modern professional journalist. To identify the components of instrumental competence that affect this key skill, we performed multiple regression analysis. To do this, the “ability to work with social networks” is taken as a dependent variable (Y), all other characteristics included in the questionnaire – as independent variables (X_n). Step-by-step selection made it possible to exclude from the regression model parameters that do not significantly affect the dependent variable (the results of the analysis are presented in Table 2).

Table 2. The results of regression analysis on the characteristics of “ability to work with social networks”

Model components	Non-standardized odds		Standardized odds	T	P-value
	B	SD	Beta		
(Constant)	4.474	0.562		7.967	0.000
Ability to use social media for research (X_1)	0.242	0.057	0.307	4.244	0.000
Knowledge of Internet content legal regulation (X_2)	0.157	0.052	0.207	3.007	0.003
Knowledge of mobile journalism features (X_3)	0.130	0.064	0.164	2.020	0.045
Photo processing skills (X_4)	0.250	0.057	0.331	4.357	0.000
Ability to visualize data, create Infographics (X_5)	-0.178	0.064	-0.214	-2.776	0.006

Thus, the dependence of the ability to work with social networks on other components of instrumental competence is expressed by the formula (1):

$$Y = 4.474 + 0.307(X_1) + 0.207(X_2) + 0.164(X_3) + 0.331(X_4) - 0.214(X_5) \quad (1)$$

The next stage of the study results was a common factor analysis of the numerical indicators of the respondents’ assessment of ICJ components, implemented using the statistical analysis software STATISTICA 6.0 and IBM SPSS Statistics.

The feasibility of performing factor analysis is confirmed by calculating Bartlett’s Test of Sphericity, which is 0.0002, and by calculating the Kaiser-Meyer-Olkin Measure of Sampling Adequacy (KMO), which is 0.898.

The using of the Scree test (Cattel criterion) [20] made it possible to determine four significant factors (Fig. 1) with a total variance of the mean distribution of 61%.

The average value of the correlation between the factors is 0.259, and the average value of the internal consistency of the factors is 0.763, which allows us to talk about their stability.

Dominant loadings (≥ 0.500000) were estimated from the four-factor structures by the assessed variables, which made it possible to determine the major and significant components for each factor (classify ICJ components into 4 significant groups for recipients).

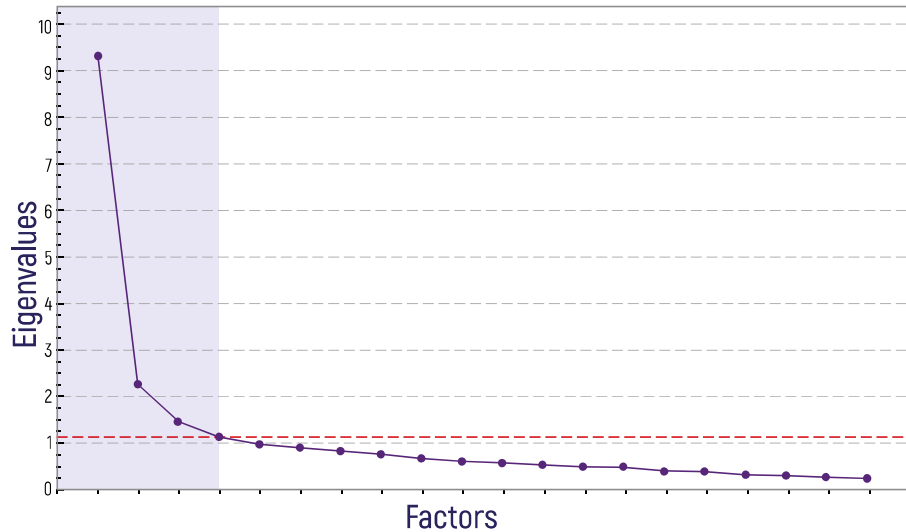


Fig. 1. Determination of factors number by Cattell criterion

4 Main results of the research

The result of the first stage of the study data analysis is a formula derived from the results of multiple regression, which allows us to conclude that in the opinion of recipients, to successfully master the ability to work with social networks enough to master five skills, the most important of which are the ability to use social media for research and photo processing skills (the other three are knowledge of Internet content legal regulation, knowledge of the features of mobile journalism and the ability to visualize data and create Infographics).

The result of the second stage of the data analysis is the distinguishing of 4 groups of ICJ components, summarized by the authors of the article under conditional names, which can be discussed. The first single factor (the group of ICJ components) that accounts the largest share of the total variance (20.47%) with the eigenvalue 4.709 is “Web Publishing Skills” includes the following components (listed in order of decreasing factor loadings): knowledge of programming languages (factor loading is 0.864); knowledge of website development tools (0.807); knowledge of CMS tools (0.735); knowledge of data analysis software (0.678); knowledge of Photoshop, Illustrator, InDesign software (0.617); ability to visualize data, create infographics (0.598); design and page making skills of digital media (0.559); ability to optimize content to SEO systems (0.538); knowledge of Web design basics and skills (0.511).

The second most important factor (eigenvalue 3.914, the share of total variance 17.01%) is “Cybersecurity Skills” covers the skills of monitoring online publications, print media and television (0.800); knowledge of network security rules (0.747); knowledge of Internet content legal regulation; (0.620); knowledge of Internet theory and Internet technologies (0.608); media product promotion (0.553); knowledge of the

mobile journalism features (0.533); ability to work with social networks (0.528); ability to use social media for research (0.526).

The third factor (characterized by an eigenvalue 3.728, a share of the total variance 16.21%) is “Multimedia content preparation skills”: the ability to edit video (0.907); photo processing skills (0.827); knowledge of the rules and skills of filming (0.775); knowledge of Web design basics and skills (0.568); design and page making skills of digital media (0.508).

The fourth factor (the least significant – the eigenvalue is 1.676, the share of the total variance 7.28%) is “Knowledge of media product promotion tools”: knowledge of dashboards, social media functionality (0.635); digital marketing skills (0.547).

Table 3. Comparison of ICT components of journalists’ professional training with respondents’ views of professional instrumental competence

ICJ Components Groups (Respondents’ Views)	Compulsory Disciplines	Optional Disciplines (selected by respondents in 2019)	Optional Disciplines (full list)
Web publishing skills	New Media		SEO-copywriting Website support Content management systems
	Cross-media Journalism	SEO copywriting	Multimedia news portal Creating and promoting a new site Effective presentation tools
	Web-design in the media		
Cyber-security skills	-	-	-
Multimedia content preparation skills	Television production		Advertising design workshop Mediadesign Fact-checking and verification
	Photojournalism	Advertising design workshop	Storyboards in multimedia projects
	Internet media content	Mediadesign	Visual statistics Modern cross-media communications Advertising and PR on the Internet
Knowledge of media promotion tools	Mediametry	-	Television Marketing Media Marketing Internet media analytics

Consequently, according to the results of the first-year student survey, four significant groups of ICJ components were identified (listed in descending order of importance): web-publishing skills; cyber-security skills, multimedia content preparation skills and knowledge of media promotion tools.

The analysis of the educational-vocational programs' components, which the students (who took part in the survey) study, made it possible to test the hypothesis about the dependence of the subjects' choice on the respondents' views about the ICT skills required in journalism practice. For this purpose, from the whole set of disciplines, based on the study of available annotations, those, aimed at the ICJ formation were selected. The results are summarized in Table 3.

It should be noted that the list of compulsory disciplines in different universities is predominantly established, at the same time the blocks of optional disciplines differ depending on the specifics of the educational institution and the specializations offered in it (according to item 5 of Article 10 of the Law "On Higher Education of Ukraine" higher education institution within the licensed speciality may introduce specializations, the list of which is determined by the higher education institution [3]). Analyzing Table 3, we can observe trends in students' choice of disciplines that are not duplicated in content with the compulsory disciplines and complement them according to respondents' views about ICJ. At the same time, no specific disciplines have been identified for the development of the second-largest group of ICJ components (cyber-security skills). It may be assumed that the information required to form the skills of this group is part of other disciplines.

5 Conclusions, discussions and prospects of further researches

Our research has made it possible to draw the following main conclusions.

The use of ICT in the professional training of journalists is due not only to the methodological features of the educational process organization but also to the demands of the labour market for the journalists' professional competence. According to the world scientific opinion, instrumental competence knowledge is one of the basic requirements for the professional training of higher education institutions graduates in the speciality 061 "Journalism". Its components include knowledge of software, technology and special equipment, Internet tools and services required at every stage of journalists' professional activity realization (from design to creating and distributing media products) and the ability to use their capabilities following professional tasks. Disputable remains the question of the need for journalists' knowledge of programming languages: some researchers believe that knowledge of basic coding principles are sufficient for productive collaboration with programmers, while others believe that mastering journalists' coding language is necessary. In support of this view, C. Royal cites the example of advertisements by some employers, whose inquiries state that a candidate applying for a journalist position must know modern programming languages [11, p. 386]. According to Dan Gillmor, journalists need to understand the basic principles of programming in a reality where "computer code is more often part of everything we touch and the services we use" [21, p. 816]. In this regard, the author believes that in the course of professional training students should take at least a short JavaScript course or gain basic knowledge to work with programmers [21, p. 816]. An analysis of educational programs in the speciality 061 "Journalism" in Ukrainian

universities revealed that most disciplines aimed at mastering analyzed ICT skills, which are components of journalists' instrumental competence, are mostly grouped into specialized courses, often grouped into one of the sample blocks. This means, that if all such disciplines were selected (which is impossible given certain limitations), their total amount would be no more than 25% of ECTS credits. In this aspect, it is necessary to draw attention to the Paris Declaration of Freedom of Journalism Education (2019) concluded by the World Journalism Education Council, one of the points of which is the recognition of the need to maintain a balance between academic knowledge and technical skills of journalistic craft [22]. Second, such a principle of composing academic disciplines makes it difficult for students to choose from the list of disciplines, those, that most closely meet the contemporary professional needs of journalists. Such an opinion can be explained on the example of the study of first-year students' views about the ICJ components. Thus, the results of this study are ICT skills rating, compiled by the average values of the survey results, and groups of ICT skills, that are separated by factor analysis of the survey numerical results. A comparison of these results showed that some of the evaluated variables are of different significance. For example, the "knowledge of programming languages" in the overall ICT skills rankings comes in at 4.91, which is "not very important (rarely required)". At the same time, the same variable ("knowledge of programming languages") has the highest factor loading in the most meaningful factor structure defined by the authors as "Web publishing skills" and is logically combined with other components of this factor. Another example is the variable "ability to write texts for mobile devices/Internet", which is ranked the second with a score of 9.04 in the overall ranking, but in none of the four distinguished factor structures (ICT skills groups) by factor analysis results not hit without having a sufficient factor loading. Such result is quite logical since the ability to write texts relates to the fundamental skills of journalists (is a part of the ability to write texts for different types of media) and applies only indirectly to ICT.

The examples below indicate the difficulty of ranking the offered variables, filed with the solid list: some of them may be equivalent, however, the respondents' awareness of this is complicated by the fact that they are assigned to one group, which, in connection with the principle of the formation of optional disciplines, may mean the need for review (perfection) mechanism for grouping both the disciplines themselves and their blocks.

The results of regression analysis of the survey data allow teachers to analyze the learning needs of students who participated in the survey; their idea of the skills most necessary for professional activity; to determine which ones they prefer and which ones are out of their sight. This information will help to monitor whether local and global training goals have been achieved, to optimize the methodology of professional training of journalists, in particular in the organization of such pedagogical activities that will help (if necessary) adjust students' perceptions of necessary professional skills.

The consideration of factor analysis results makes it possible to conclude that students' ideas of the ICJ components are consistent with contemporary scientific thought. For example, the identified factor structures correspond to the main ICT skills groups that are highlighted in the Model curricula for journalism education [17], summarized by the World Journalism Education Council, and correlated with the

specific competencies defined in the Higher Education Standard in journalism [4]. At the same time, the received factor structures are an indicator of students' educational needs and expectations, information about which can be used to 1. Analyze the adequacy of students' views of the profession and, if necessary, adjust them; 2. Predicting students' professional development; 3. Improving the content and methods of teaching educational disciplines. In this regard, the methodology of analyzed research can be used to develop one of the components of an educational data analysis system and can be used regularly because the results of the study characterize a particular sample of 2019–2020 first-year students. Students who will enter the speciality 061 “Journalism” in the next and subsequent years are likely to have different ideas because they are in a different information space (which changes according to significant socio-political conditions and scientific and technological development). Thereby, the data that characterizes a specific sample of students will enable teachers to respond promptly to the educational needs of future journalist professionals.

Therefore, such promising areas for further research can be identified: development of an automated system of perception data analysis in the field of journalism education to track the dynamics of students' professional development based on their views about the various components of journalists' professional competence; a comparison of the study results to identify relevant views of students, teachers and potential employers to synchronize them in the aspect of improving journalism education.

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Education Statistics: Looking for a Case-study for Modelling

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Abstract. The article deals with the problem of using modeling in social statistics courses. It allows the student-researcher to build one-dimensional and multidimensional models of the phenomena and processes that are being studied. Social Statistics course programs from foreign universities (University of Arkansas; Athabasca University; HSE University, Russia; McMaster University, Canada) are analyzed. The article provides an example using the education data set – Guardian UK universities ranking in Social Statistics course. Examples of research questions are given, data analysis for these questions is performed (correlation, hypothesis testing, discriminant analysis). During the research the discriminant model with group variable – modified Guardian score – and 9 predictors: course satisfaction, teaching quality, feedback, staff-student ratio, money spent on each student and other) was built. Lower student’s satisfaction with feedback was found to be significantly different from the satisfaction with teaching. The article notes the modeling and statistical analysis should be accompanied by a meaningful interpretation of the results. In this example, we discussed the essence of university ratings, the purpose of Guardian rating, the operationalization and measurement of such concepts as satisfaction with teaching, feedback; ways to use statistics in education, data sources etc. with students. Ways of using this education data in group and individual work of students are suggested.

Keywords: education statistics, Social Statistics courses, Guardian methodology, university score, Excel, SPSS, correlation, hypothesis testing, discriminant analysis

1 Introduction

1.1 Setting of a problem

The modern world is characterized by the diversity of data circulating in society and waiting to be researched [1-3]. The European Digital Competence Framework for Citizens defines information and data literacy as important component of digital competence [2]. The Program for the Development of National Statistics by 2023 [3], adopted by the Cabinet of Ministers of Ukraine (Resolution No. 222 of February 27, 2019), states, in particular, that the level of statistical literacy of the society needs to be

improved. Therefore, training of the specialists who can make data-based decisions is an important task of both national and international education. One of the important aspects of such training is the formation of student's competences in building statistics models for studying social phenomena.

The aim of the article, based on the data sets from Guardian UK university ranking show steps for building one-dimensional and multidimensional models in education statistics.

1.2 Analysis of recent research and publications

Researchers who have studied various aspects of statistical (data) literacy are: Iddo Gal, Ellen Mandinach, Chantel Ridsdale, Siu-Ming Tam, Nigel Cross, W. Pat Taylor, Anthony M. Townsend, Jane M. Watson, Rosemary A. Callingham, Robert Gould, Ruth Krumhansl, Catherine D'Ignazio, Rahul Bhargava, William Finzer [4].

Many scholars are interested in the problems that arise in teaching statistics and data analysis. The study of Svetlana Tishkovskaya and Gillian Lancaster [5] summarizes the list of such problems. The main problems are the following:

- Focus on mathematical and mechanical aspects of knowledge.
- “Math-phobia”, “statistical anxiety” and lack of interest.
- Shortage of students with basic statistical knowledge.
- Statistics courses are conducted without reference to the subject area.
- Lack of statistical literacy and inability of students to use statistics in daily life.
- Lack of tools for assessing statistical thinking and statistical literacy of the population in social settings.

To overcome these problems, the following strategies are proposed based on the analysis of [5]:

- Integration of statistical thinking and statistical literacy into curricula of different disciplines;
- Use of media and newspaper articles to evaluate students' and students' ability to interpret statistical thinking.
- Shifting the focus of statistics into curricula from mathematical calculations to tasks of a practical nature.
- Problem solving skills development: students are offered open problems and the teacher takes on the role of a “facilitator” in the learning process.
- Using real life examples in project work.
- Development of student motivation strategies.
- Development of statistical literacy and critical thinking skills, use of examples of incorrect analysis.
- Focus on daily arguments that use statistics as evidence.

In [4] new forms of student's activity related to data analysis introduced by academics and practitioners are discussed: building art objects and storytelling based on data;

shared data collection by citizens through mobile devices, “play with data” using modern data visualization services.

The different problem of computer modeling in education are summarized by Ukrainian scientists in framework of CoSinE-2019 workshop. Serhiy O. Semerikov and other studied computer simulation of neural networks using spreadsheets [6]; Oleksandr H. Kolgatin and other discussed about computer simulation as a method of learning research in computational mathematics [7]; Vladimir N. Soloviev and other presented report of modeling of cognitive process using complexity theory methods [8].

The issues of preparing sociology students and future PhDs to use statistics models during analysis social statistics data are debated in papers [9-12].

2 Results of the study

During our research we analyzed several Social Statistics course programs from foreign universities [13-17].

In the research University of Arkansas at Little Rock the SOCI-3381 course is taught to Sociology majors [13]. The course deals with basic statistical techniques and their theoretical premises, which are often used in statistical reasoning in sociology: qualitative variables, characteristics of attributes, variation, correlation, tests of significance. Course consists of three credit hours.

The course Sociology 301: Social Statistics by the Athabasca University provides an overview of the uses of statistical analyses for the social sciences. The textbook for this course is [18]. Course consists of 11 units [14]:

- Introduction to Statistics and Displaying Information in Tables and Graphs
- Measures of Central Tendency and Variability
- Correlation and Prediction
- Some Key Ingredients for Inferential Statistics: The Normal Curve, Sample versus Population, and Probability
- Introduction to Hypothesis Testing
- Hypothesis Tests with Means of Samples
- Making Sense of Statistical Significance
- Introduction to the t Test
- The t Test for Independent Means
- Introduction to the Analysis of Variance
- Chi-Square Tests

The learning goals of the Economic and Social Statistics Course of HSE University (Russia) [15] is understanding basic principles of collecting and using data from various statistical sources; familiarization with main statistical indicators used in different fields of social science; introduction to basic programming tools in STATA programming package. The course covers the following topics: a short introduction into principles of collecting and using data from various data sources; data sources on six topics which include: labor market, household welfare, poverty and inequality, health, education and economic development.

Sociology 6Z03 is an introductory Social Statistics course by the McMaster University, Canada [16]. The principal goal of this course is to introduce students to the fundamentals of statistical reasoning and to the role of statistical methods in social research. At the end of the course students should be able to read sociological research that uses basic statistical methods; to undertake elementary data analysis; and to take more advanced courses in Social Statistics. The textbook for the course is [19]. Course objectives are:

- Conduct univariate, bivariate, and introductory multivariate analyses and choose an appropriate analytical technique depending on the levels of measurement of variables of student's interest.
- Design a quantitative research project and write a research paper that can be presented in an academic sociology conference (e.g. Canadian Sociological Association annual meetings).
- Operationalize concepts and social phenomena of student's interest and to derive hypotheses that can be tested using survey data.
- Write syntax for managing data and conducting analysis using statistical software (SPSS or PSPP).
- Download public use microdata and read the dataset on SPSS (or PSPP).
- Analyze public use microdata (e.g. GSS, ISPP, Censuses) using relevant documents (e.g. codebooks, data dictionaries, questionnaires).
- Effectively present findings from data analysis using PSPP (or SPSS), Excel, and PowerPoint.
- Read and critique academic sociology journal articles that are using basic social statistics.

Sociology 740 is a second (more advanced) Social Statistics course from McMaster University, Canada. This course focuses on regression analysis, linear models, and generalized linear models, such as logistic regression and Poisson regression. One of the goals of the course is to introduce students to modern statistical computing [17]. The textbooks for the course are [20-21].

Analysis of the courses programs allows making such conclusions. Most Western courses in Social Statistics are introductory statistics courses for sociology majors [13, 14, 16]. We see a slightly different approach in the domestic tradition, where Social Statistics courses are taught to students after taking the introductory course of mathematical and statistical methods. At National Technical University of Ukraine "Igor Sikorsky Kyiv Polytechnic Institute" Social statistics course is a second-year course for sociology majors. This course is preceded by a mathematical methods course (3 semesters), so there is every reason to use these methods when analyzing social statistics data in different areas of social life: education, health, labor, population and other.

An important problem in data analysis teaching is the formation of student's motivation. One example of the formation of positive educational motivation, in our view, is the use of interesting data sets relevant to learner area. One of the most important sections of social statistics is education statistics. One of the main objectives

of the statistical study of education is the study of the state and development of educational institutions.

University rankings are a useful example of measurement in education statistics. There are many different methodology of universities rankings [13]. In looking for data for our case-study, we settled on the UK experience. Each year, three national university rankings are published there. They are: The Complete University Guide [14-15], The Guardian [16] and the guide jointly published by The Times and The Sunday Times. The primary aim of these rankings is to inform potential undergraduate applicants about UK universities based on a range of criteria.

Consider how you can use the Guardian ranking in teaching the analysis of educational statistics. First, you can show students, by way of example, how to retrieve raw data from web pages and then prepare them for analysis.

So, first, we recommend that students go to the following page: <https://www.theguardian.com/education/ng-interactive/2019/jun/07/university-league-tables-2020>.

The variables that students see in the table have the following explanation:

1. Guardian ranking for this year
2. Guardian ranking for last year
3. Name of university
4. The Guardian score, out of 100, is a rating of excellence based on a combination of all the other factors
5. Course satisfaction: the rating for the overall quality of the course, given by the final-year students in the latest National Student Survey (NSS)
6. Teaching quality: the rating for the quality of teaching on the course, given by the final-year students in the NSS
7. Feedback: the rating for the quality of feedback and assessment, given by the final-year students in the NSS
8. Staff-student ratio: the number of students per member of teaching staff
9. Spend per student: money spent on each student, excluding academic staff costs, given as a rating out of 10
10. Average entry tariff: typical Ucas scores of young entrants (under 21) to the department
11. Value-added score: this compares students' degree results with their entry qualifications, to show how effectively they are taught. It is given as a rating out of 10.
12. Career after six months: percentage of graduates who find graduate-level jobs, or are in further study at professional or HE level, within six months of graduation. It reflects how good the university is at employability.
13. Continuation rate: the percentage of first-year students continuing to second year [16].

The next step is to read the data and transfer it to Excel. The following steps can be followed:

First step: open Excel.

Second step: select **Data > From Web**. Enter the url of the web-page in the address box of the **From Web** window, select “Table 0” object, click **Transform Data** and edit data types in **Power Query Editor**. Then click **Close & Load** (Fig. 1).

The screenshot displays the Power Query Editor interface. On the left, the Navigator pane shows a folder containing 'Table 0'. The main window, titled 'Table 0', shows a table with two columns: '2020' and '2019'. The data rows are as follows:

2020	2019
1	1
Satisfied with course The rating for the overall quality of the course, given	Satisfied with cou
2	3
Satisfied with course The rating for the overall quality of the course, given	Satisfied with cou
3	2
Satisfied with course The rating for the overall quality of the course, given	Satisfied with cou
4	4
Satisfied with course The rating for the overall quality of the course, given	Satisfied with cou
5	5
Satisfied with course The rating for the overall quality of the course, given	Satisfied with cou
6	6
Satisfied with course The rating for the overall quality of the course, given	Satisfied with cou
7	9
Satisfied with course The rating for the overall quality of the course, given	Satisfied with cou
7	7
Satisfied with course The rating for the overall quality of the course, given	Satisfied with cou
9	8
Satisfied with course The rating for the overall quality of the course, given	Satisfied with cou
10	14
Satisfied with course The rating for the overall quality of the course, given	Satisfied with cou
11	10

At the bottom of the 'Table 0' window are buttons for 'Load', 'Transform Data', and 'Cancel'. Below this is the main Power Query Editor window, titled 'Table 0 - Power Query Editor'. The ribbon includes 'File', 'Home', 'Transform', 'Add Column', and 'View'. The 'Transform' tab is active, showing options like 'Close & Load', 'Refresh', 'Advanced Editor', 'Choose Columns', 'Remove Columns', 'Reduce Rows', 'Split Column', 'Group By', 'Data Type: Text', 'Combine', 'Manage Parameters', 'Data source settings', and 'New Source'. The 'Query Settings' pane on the right shows the 'APPLIED STEPS' list with 'Source', 'Navigation', and 'Changed Type'.

Fig. 1. Retrieve web page data

This is what the raw data sheet looks like (Fig. 2).

	A	B	C	D	E	F	G	H
1	2020	2019	Institution	Guardian score	Satisfied with	Satisfied with	Satisfied with	Student to sta
2	1	1	Cambridge	100	n/a	n/a	n/a	11.2
3	Satisfied with col			Satisfied with col	Satisfied with course	The rating for the overall quality of the cours		
4	2	3	St Andrews	97.9	93	93	80	11.7
5	Satisfied with col			Satisfied with col	Satisfied with course	The rating for the overall quality of the cours		
6	3	2	Oxford	97.6	n/a	n/a	n/a	10.4
7	Satisfied with col			Satisfied with col	Satisfied with course	The rating for the overall quality of the cours		
8	4	4	Loughborough	83.4	88	88	75	13.4
9	Satisfied with col			Satisfied with col	Satisfied with course	The rating for the overall quality of the cours		
10	5	5	Durham	81.6	85	85	72	15
11	Satisfied with col			Satisfied with col	Satisfied with course	The rating for the overall quality of the cours		
12	6	6	Bath	80	86	87	69	15.6
13	Satisfied with col			Satisfied with col	Satisfied with course	The rating for the overall quality of the cours		
14	7	7	Imperial College	79.3	82	84	64	11.4
15	Satisfied with col			Satisfied with col	Satisfied with course	The rating for the overall quality of the cours		
16	7	9	Lancaster	79.3	89	87	74	12.6
17	Satisfied with col			Satisfied with col	Satisfied with course	The rating for the overall quality of the cours		
18	9	8	Warwick	73.9	86	86	70	13
19	Satisfied with col			Satisfied with col	Satisfied with course	The rating for the overall quality of the cours		
20	10	14	Exeter	73.2	87	89	74	15.9
21	Satisfied with col			Satisfied with col	Satisfied with course	The rating for the overall quality of the cours		
22	11	10	Leeds	71.8	88	90	73	13.4
23	Satisfied with col			Satisfied with col	Satisfied with course	The rating for the overall quality of the cours		

Fig. 2. Raw data

The next, third step is to remove everything from this data sheet, to leave only the data for 121 universities; it is advisable to use sorting by column 2020.

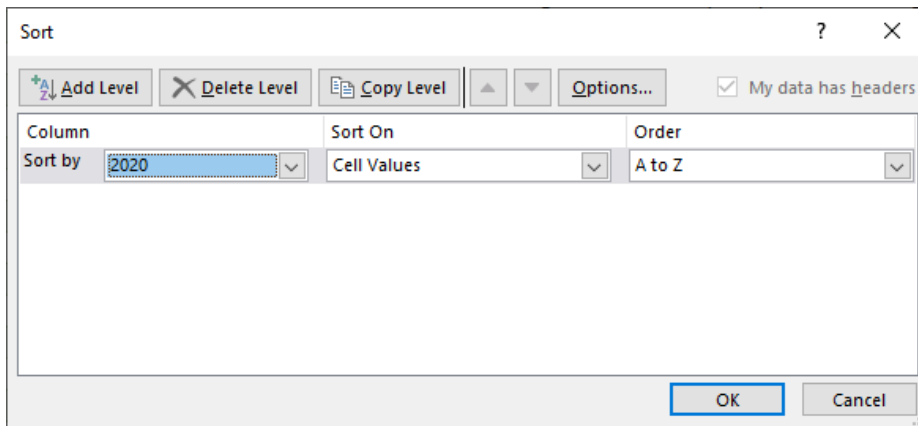


Fig. 3. Data sorting

The fourth step is to change the semicolon in all columns that contain non-integers. As a result (Fig. 4), we get the following table (showing a fragment for 20 universities).

The students then save the file, create a similar file in SPSS, and analyze the data.

In the experiment we conducted, the students worked in pairs, they had to put forward three statistical hypotheses regarding the data and test them. An analysis of students' work showed that they used correlation confidently and be able to construct a scatterplot; two groups of students conducted cluster analysis, all group used

descriptive statistics. There were difficulties with exporting this data as a .csv file in SPSS. Therefore, during the lecture we showed a visual presentation “How to export a .csv file to SPSS”.

	A	B	C	D	E	F	G	H	I	J	K
1	2020	2019	Institution	Guardian score	Satisfied with	Satisfied with	Satisfied with	Student to sta	Spend per stu	Average entry	Value added
2	1	1	Cambridge	100	n/a	n/a	n/a	11.2	9.8	224	6
3	2	3	St Andrews	97.9	93	93	80	11.7	6.1	208	6.6
4	3	2	Oxford	97.6	n/a	n/a	n/a	10.4	10	215	6.8
5	4	4	Loughborough	83.4	88	88	75	13.4	5.9	162	6.2
6	5	5	Durham	81.6	85	85	72	15	5.3	195	7
7	6	6	Bath	80	86	87	69	15.6	6.2	182	6.8
8	7	7	Imperial College	79.3	82	84	64	11.4	8.6	206	5.9
9	7	9	Lancaster	79.3	89	87	74	12.6	8	157	4.7
10	9	8	Warwick	73.9	86	86	70	13	7.7	180	5.5
11	10	14	Exeter	73.2	87	89	74	15.9	3.5	172	6.4
12	11	10	Leeds	71.8	88	90	73	13.4	7	166	7
13	12	16	Nottingham Tren	71.2	88	87	80	14.5	4.6	136	5.2
14	13	n/a	Uni for the Creat	71.1	83	85	81	12.9	7.7	144	5.1
15	14	24	Glasgow	70.9	87	90	69	13.7	5.5	200	5.8
16	15	13	Coventry	70.6	87	89	74	14.6	6.2	125	6.9
17	16	19	Birmingham	69.8	86	88	69	13.9	7.4	165	6.7
18	17	22	Lincoln	69.2	89	88	75	14.7	3.9	128	5.3
19	18	17	Nottingham	67.8	84	87	70	14.5	6.2	161	6.2
20	19	15	London School of	66.6	69	75	57	11.1	8.6	190	6.1
21	20	12	York	66.5	85	88	75	14.6	5.5	158	4.7

Fig. 4. Fragment of the cleared data

For teachers working with students of different majors, note that you can get a workbook with different majors on different sheets (https://uploads.guim.co.uk/2019/06/04/Guardian_University_Guide_2020.xlsx).

	A	B	C	D	E	F
1	rank2020	Name of Provider	recenthistory	Average Teaching Score	% Satisfied with Teaching	% Satisfied with course
2	1	Cambridge	1->1->1->1	100,0		
3	2	St Andrews	3->3->3->2	97,9	93,2	93,4
4	3	Oxford	2->2->2->3	97,6		
5	4	Loughborough	4->6->4->4	83,4	87,7	88,0
6	5	Durham	6->4->5->5	81,6	85,3	84,6
7	6	Bath	10->5->6->6	80,0	87,2	85,9
8	7	Lancaster	8->9->9->7	79,3	86,9	88,6
9	7	Imperial College	7->6->7->7	79,3	83,5	81,9
10	9	Warwick	9->8->8->9	73,9	86	85,5
11	10	Exeter	11->13->14->10	73,2	88,9	87,1
12	11	Leeds	16->14->10->11	71,8	89,6	88,0
13	12	Nottingham Trent	53->34->16->12	71,2	87	87,9
14	13	University for the Creative Arts	->->->13	71,1	84,8	82,5
15	14	Glasgow	26->23->24->14	70,9	89,8	87,0
16	15	Coventry	15->12->13->15	70,6	88,6	86,6
17	16	Birmingham	13->15->19->16	69,8	88,4	86,1
18	17	Lincoln	56->47->22->17	69,2	87,6	88,6
19	18	Nottingham	25->19->17->18	67,8	86,8	84,2
20	19	London School of Economics	12->15->15->19	66,6	74,9	69,1
21	20	York	19->17->12->20	66,5	88,1	84,7
22	21	Portsmouth	43->37->25->21	66,1	86,6	87,6

Fig. 5. Fragment of workbook for different majors of the UK universities

We apply correlation analysis, hypothesis testing, and discriminant analysis to these data by raising relevant research questions.

Question 1. Is there a correlation between university ranks in 2020 and 2019?

We obtained a significant correlation at the level of 0,001; Spearman correlation coefficient is 0,940 and Kendall's coefficient is 0,803. That is, university rankings are consistent. Universities that have improved and worsened their ranks should be considered separately.

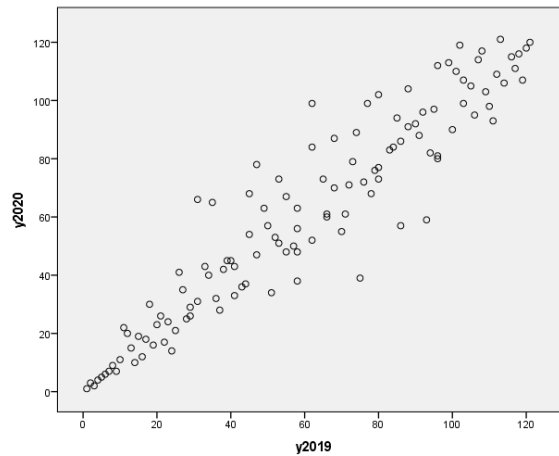


Fig. 6. Scatter diagram. Correlation between university ranks in 2020 and 2019

We also found a positive correlation between course satisfaction and satisfaction with teaching; Pearson correlation coefficient is 0,871 and it is significant at the level of 0,001. Similarly, we also found a positive correlation between learning satisfaction and feedback satisfaction; Pearson's correlation coefficient is 0,544 and is significant at 0,001.

Question 2. The next research question is whether the average satisfaction with teaching and the average satisfaction with feedback differ. To answer this question, students can use a Paired Student Test to compare the mean of the two groups

Paired Samples Statistics

		Mean	N	Std. Deviation	Std. Error Mean
Pair 1	Satisfiedwithteaching	85,13	119	3,126	,287
	Satisfiedwithfeedback	72,26	119	4,486	,411

Paired Samples Test

		Paired Differences				t	df	Sig. (2-tailed)	
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
					Lower				Upper
Pair 1	Satisfiedwithteaching - Satisfiedwithfeedback	12,866	3,840	,352	12,168	13,563	36,550	118	,000

Fig. 7. Paired Samples Test

We can observe that these differences will be significant at the level of 0,001; the Student's Test value is 36.

Question 3. The next question is whether certain variables will be distributed normally. We use the Kolmogorov-Smirnov Test and construct a histogram with a curve of normal distribution.

One-Sample Kolmogorov-Smirnov Test

		Satisfiedwithc ourse	Satisfiedwithf eedback	Satisfiedwitht eaching
N		119	119	119
Normal Parameters ^{a,b}	Mean	83,31	72,26	85,13
	Std. Deviation	4,135	4,486	3,126
Most Extreme Differences	Absolute	,124	,082	,131
	Positive	,070	,068	,081
	Negative	-,124	-,082	-,131
Test Statistic		,124	,082	,131
Asymp. Sig. (2-tailed)		,000 ^c	,048 ^c	,000 ^c

- a. Test distribution is Normal.
- b. Calculated from data.
- c. Lilliefors Significance Correction.

Fig. 8. Kolmogorov-Smirnov test

We see that the Kolmogorov-Smirnov criterion indicates a significant difference in distribution from normal for these variables.

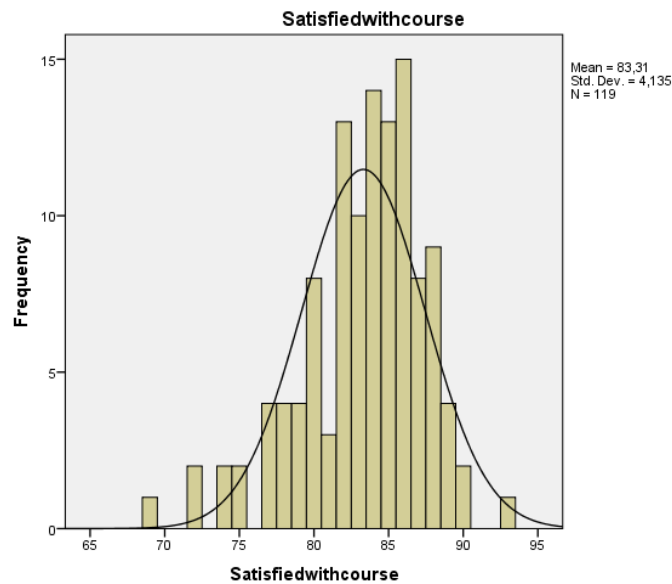


Fig. 9. The histogram with a curve of normal distribution for “satisfied with course”

We show how multidimensional methods can be applied to this data, including discriminant analysis. To do this, we introduce new variable with gradations: 1) a low-ranking university, 2) a high-ranking university. These include the first group – universities whose Guardianscore100, below the median; the second group – universities whose Guardianscore100, higher the median.

The median for the Guardianscore100 variable is 53,3. We then transcoded the Guardianscore100 into a new Guardianguroup variable, and received a frequency distribution. The first group included 61 universities, the second 60 (50,4% and 49,6% respectively).

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	low	61	50,4	50,4	50,4
	high	60	49,6	49,6	100,0
	Total	121	100,0	100,0	

Fig. 10. Frequency distribution by Guardianguroup

We then constructed a discriminant model using the Guardianguroup variable as a group variable and the other variables as the predictors. A linear discriminant analysis was conducted using 9 predictors – independent variables: who defined the affiliation of the university to one of two groups: low-ranking, high-ranking. To determine the coefficients of the discriminant function, a direct method was used in which the discriminant function was calculated with all predictors simultaneously entered. In this case, each independent variable is taken into account.

The Fig. 12 shows group statistics and Fig. 11 – the results of the test about significantly different variables in each group. For this purpose, Wilks-Lambda test value are given and a simple ANOVA is applied. One-way ANOVA showed that groups differ significantly by all variables, except “satisfied with feedback” (at 0,001 level).

	Wilks' Lambda	F	df1	df2	Sig.
Satisfiedwithcourse	,865	18,251	1	117	,000
Satisfiedwithteaching	,874	16,847	1	117	,000
Satisfiedwithfeedback	,999	,103	1	117	,749
Spendperstudent10	,854	20,049	1	117	,000
Studenttostaffratio	,717	46,254	1	117	,000
Valueaddedscore10	,898	13,312	1	117	,000
Continuation	,668	58,080	1	117	,000
Careerafter6months	,689	52,879	1	117	,000
Averageentrytariff	,711	47,526	1	117	,000

Fig. 11. Tests of Equality of Group Means

Gardiangroup		Mean	Std. Deviation	Valid N (listwise)	
				Unweighted	Weighted
low	Satisfiedwithcourse	81,836	3,6202	61	61,000
	Satisfiedwithteaching	84,049	2,8073	61	61,000
	Satisfiedwithfeedback	72,131	3,7792	61	61,000
	Spendperstudent10	4,641	1,4095	61	61,000
	Studentostaffratio	17,098	2,0265	61	61,000
	Valueaddedscore10	5,193	,9416	61	61,000
	Continuation	88,721	2,9447	61	61,000
	Careerafter6months	71,836	6,4735	61	61,000
	Averageentrytariff	124,852	15,6672	61	61,000
high	Satisfiedwithcourse	84,862	4,1016	58	58,000
	Satisfiedwithteaching	86,259	3,0640	58	58,000
	Satisfiedwithfeedback	72,397	5,1570	58	58,000
	Spendperstudent10	5,845	1,5232	58	58,000
	Studentostaffratio	14,700	1,8073	58	58,000
	Valueaddedscore10	5,807	,8899	58	58,000
	Continuation	93,034	3,2280	58	58,000
	Careerafter6months	79,759	5,3223	58	58,000
	Averageentrytariff	151,914	26,1146	58	58,000
Total	Satisfiedwithcourse	83,311	4,1349	119	119,000
	Satisfiedwithteaching	85,126	3,1260	119	119,000
	Satisfiedwithfeedback	72,261	4,4863	119	119,000
	Spendperstudent10	5,228	1,5799	119	119,000
	Studentostaffratio	15,929	2,2617	119	119,000
	Valueaddedscore10	5,492	,9634	119	119,000
	Continuation	90,824	3,7589	119	119,000
	Careerafter6months	75,697	7,1278	119	119,000
	Averageentrytariff	138,042	25,2736	119	119,000

Fig. 12. Group Statistics

From Fig. 13 we see that the Wilks criterion $\lambda = 0,40$ is significant ($p < 0,001$); the model will explain $100 - 40 = 60\%$ of data variability.

Eigenvalues

Function	Eigenvalue	% of Variance	Cumulative %	Canonical Correlation
1	1,499 ^a	100,0	100,0	,775

a. First 1 canonical discriminant functions were used in the analysis.

Wilks' Lambda

Test of Function(s)	Wilks' Lambda	Chi-square	df	Sig.
1	,400	103,053	9	,000

Fig. 13. Eigenvalues and Wilks' Lambda

The following Fig. 14 lists the unstandardized coefficients of discriminant function (b0, b1-b9).

The Fig. 15 summarizes the classification results. The redistribution of cases based on new canonical variables was quite successful: 81,9% of cases were correctly reclassified into their initial categories. An analysis of Fig. 15 shows that 93,4% of low-level observations were correctly classified and 6,6% were assigned to high-ranking

universities. 84,5% of high-level observations were attributed to their group while 15,5% were attributed to the low-rated group.

Canonical Discriminant Function Coefficients

	Function
	1
Satisfiedwithcourse	-,002
Satisfiedwithteaching	,039
Satisfiedwithfeedback	,155
Spendperstudent10	,208
Studenttostaffratio	-,221
Valueaddedscore10	,305
Continuation	,107
Careerafter6months	,053
Averageentrytariff	,017
(Constant)	-29,686

Unstandardized coefficients

Fig. 14. The unstandardized coefficients of discriminant function

Guardiangroup			Predicted Group Membership		Total
			low	high	
Original	Count	low	57	4	61
		high	9	49	58
%		low	93,4	6,6	100,0
		high	15,5	84,5	100,0

a. 89,1% of original grouped cases correctly classified.

Fig. 15. Classification results

Note that the statistical analysis should be accompanied by a meaningful interpretation of the results. In this example, we discussed the essence of university ratings, the purpose of these ratings being a guide for the future applicants and their parents, the operationalization and measurement of such concepts as satisfaction with teaching and feedback; ways to use statistics in education, data sources, etc.

The ability to visualize and interpret visual representations is one of the important parts of modeling training. In our course students were using the Education at a Glance infographic [26] for analysis and interpretation, as well as samples for visualizing data in student's course papers.

3 Conclusions and perspectives of further research

Measurements that are used in modern education statistics are becoming more and more complex. Modeling methodology helps determine the effectiveness of educational innovations in different educational contexts, and study phenomena in their interrelations; understand the influence of latent factors, develop systemic thinking.

The education statistics section in Social Statistics course provides extensive material for training data literate students. The datasets of Universities rankings can be

used in the educational process both for constructing one-dimensional models, and for constructing multidimensional models: cluster, discriminant. A Guardian ranking is accessible, open and contains criteria that are easily understood by students. Also, it is possible to conduct comparative studies with the different university majors.

As our experience shows, such data can be used in various ways. The teacher can formulate various research questions for groups of students and organize the group work; the teacher can conduct module tests on this data set, offering everyone different questions; but the best (while more difficult) way is to ask students to formulate their own questions and get answers to them. Moreover, Guardian ranking methodology can be studied in detail [25].

During this research the discriminant model of Guardian score was built. We were using the Guardian group variable as a group variable and the other variables as the predictors. A linear discriminant analysis was conducted using 9 predictors – independent variables that defined the affiliation of the university to one of two groups: low-ranking, high-ranking.

Further development of work in this direction is the creation and study structural equations model [27-28] with data set of migration statistics.

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Linux Online Virtual Environments in Teaching Operating Systems

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Abstract. The article provides an overview of Linux ready-made online environments based on various virtualization technologies. Linux ready-made online virtual environments are systematized, the advantages and disadvantages of considering groups of online virtual environments are listed. The work also gives the comparison of standalone online Unix/Linux terminals in terms of their possible use for a course in operating systems. The author analyzes the experience of teaching a Linux operating system to students of different specializations, and in particular, discusses the virtualization tools used, including Linux online environments (Amazon EC2, Cloud 9, a virtual machine for NDG Linux Essentials course). The study states the need for developing an individually designed system to provide Linux online virtual environments and elaborates the requirements to this system. The work also discusses potential challenges which the developers of Linux online virtual environments for teaching operating systems may face, including the problem of finding a balance between availability and stability of virtual environments on the one hand and the realism of students' learning experience on the other hand.

Keywords: virtualization, Linux, operating systems.

1 Introduction

A course in operating systems (OS) usually includes practical assignments on Unix-like operating systems (particularly, Linux). However, at the same time, university lab computers, students' laptops and home desktop computers mostly come with Windows installation. That is one important reason why different virtualization technologies are often used for a course in operating systems. These technologies enable working with a target operating system regardless of a locally installed operating system and without compromising the security of university lab computers. Students, who take a course, may come to class with their own laptops, as well as use lab computers, besides in some circumstances they take a course distantly. So, hardware configuration, host operating system, characteristics of network connections and other conditions vary widely. Besides, students must get feedback on their practical assignments as soon as possible, although this task could be challenging for small teaching staff working with a large number of students during the semester. Some degree of automation on checking and grading of assignments would decrease the amount of routine work and give teaching

staff the ability to pay attention to more creative assignments. In light of the above, Linux online virtual environment running from a web browser could make practical assignments more independent of software and hardware. It also could help students to get well-timed feedback on simple mistakes.

There are numerous Linux online virtual environments with different characteristics and different underlying technologies. Most of them could be at least partially used in teaching operating systems. Conversely, although we generally appreciate the idea of combining multiple virtualization tools for one course, there is still the need for a basic tool to be applied most of the time.

The purpose of the article is to investigate available ready-made Linux online environments based on different virtualization technologies and, thus, elaborate the requirements to an individually designed system which provides Linux online virtual environments.

2 Related work

Available works on development and usage of online Linux virtual environments vary greatly focusing on different approaches as well as different courses' needs. David Croft and Matthew England [1] describe the experience using Codio at Coventry University in teaching programming. Students use online virtual Linux environments provided by Codio, while teaching staff add supplemental tasks with automated feedback. David J. Malan [2] describes moving CS50, Harvard College's introductory computer science course, into the cloud provided by Amazon Elastic Compute Cloud (Amazon EC2).

Bobby Powers, John Vilks and Emery D. Berge in the work [3] present Browsix, posing it as a framework between Unix-like operating system and a web browser. Browsix is emulating core Unix features using JavaScript. Rémi Sharrock, Lawrence Angrave and Ella Hamonic [4] offer WebLinux tool providing a Linux terminal and an integrated development environment (IDE) in the browser. In this case, Linux is also emulated using JavaScript. Aristogiannis Garmpis and Nicolaos Gouvatsos [5] suggest an online environment including emulated Ubuntu Linux operating system with Graphical User Interface (GUI).

Nadiia Balyk, Yaroslav Vasylenko, Vasyl Oleksiuk and Galina Shmyger [6] describe a virtual cloud laboratory based on Apache CloudStack and EVE-NG Community and its use for teaching the CCNA Cyber Operations course. Andrii Ya. Batiuk, Dmytro Ye. Vankevych, Hryhorii H. Zlobin in [7] focus on an experience of using Proxmox VE along with OpenVZ virtual containers and KVM hypervisor for Linux System Administrating special course.

Earlier, the study on the experience of teaching OS at higher educational establishments of the world has been done [8], showing a number of common features of analysed OS courses, including the following.

- The high priority of studying Unix-like OSs (ranging from teaching OSs like Pintos to popular full-function Linux distributives like Ubuntu).

- The use of a wide variety of virtualization tools (from full emulators like QEMU to type II hypervisors like VMware Workstation, VMware Fusion or VirtualBox, as well as more specific tools like Vagrant, mCertiKOS or Cygwin).
- In many cases, the availability of at least one alternative virtualization tool along with the one applied by default.

All the above-mentioned studies have been analysed and taken into consideration while elaborating the requirements to an individually designed system which provides Linux online virtual environments.

3 Elaborating the requirements to Linux online virtual environment for teaching the operating systems course

To formulate the requirements to the system which would provide Linux online virtual environments we need to analyse the needs of the course, taking into account its possible future development.

3.1 Previous theoretical and practical research

Our previous work [9] develops the methodology for using Unix-like OS virtualization technologies in training bachelors of Informatics based on the varied approach to applying before-mentioned technologies.

The approach involves combining several virtualization tools for meeting individual features of a course, individual students' needs and ensuring hardware and software fault tolerance. The work specifies the procedure for selecting virtualization tools in teaching OS to bachelors of Informatics. Following the suggested methodology, the study also developed the *Operating Systems and System Programming* handbook for future bachelors of Informatics and methodological guidelines *Virtualization Technologies in Teaching Operating Systems to Bachelors of Informatics* for teachers of higher educational establishments. During the implementation of the methodology in Zhytomyr Ivan Franko State University (2016–2018) we have been using the following tools.

- Oracle VirtualBox
- Amazon EC2 t2.micro instances
- Cloud 9 IDE
- Laptops with Linux (Ubuntu distributive)

The situation with Cloud 9 IDE is described in subsection 3.3. Amazon EC2 instances were used as a supportive tool mainly because of low network bandwidth causing considerable latency.

3.2 Reflection on recent practical experience

Later experience involved teaching two courses in operating systems in Zhytomyr Polytechnic State University (from September 2019 till now).

The first course, Unix/Linux Operating Systems, was held from September 2019 to December 2019 and was attended by third-year students of Computer Engineering and Cybersecurity specializations.

The second course, Operating Systems, started in February 2020 and was attended by second-year students of Computer Engineering, Cybersecurity, Software Engineering specializations.

Throughout the mentioned courses, the students and the teaching staff were using multiple tools for practical assignments. These tools are listed below and include both locally installed applications and remotely accessed environments.

- Virtual machine from NDG Linux Essentials course [10] (available on CISCO Networking Academy)
- Oracle VirtualBox
- Laptops with Linux (namely Ubuntu and Arch distributives)
- Amazon EC2 t2.micro instances (intermittently)

Experience of teaching these two courses revealed the need for a virtual environment which would provide access to fully functioning Linux installation, supporting most of the course practical assignments.

Concerning Unix/Linux Operating Systems course, virtual machine from NDG Linux Essentials met almost all the requirements of the course, except networking (and, thus, manipulating software packages) and the impossibility to save students' files between reboots.

According to the needs of our current courses in operating systems, the list of major features an online environment should have is as follows.

- The support of most administrative and non-administrative commands the typical Linux installation would have.
- Giving administrative privileges to students inside the virtual environment.
- The support of basic networking operations (changing network configuration, *ping* etc.).
- The support of uploading/downloading files to/from virtual environments.
- The ability to keep guest OS up-to-date.
- The support of bash scripting.
- The ability to save students' files in guest OS between reboots.

3.3 An overview of available ready-made Linux online virtual environments

Online tools for working with Unix/Linux operating systems through the web browser or other networking clients vary greatly depending on the functionality they provide, conditions they are available on, underlying technologies et al. All the Unix/Linux online virtual environments could be divided into the following groups.

- Standalone online Unix/Linux terminals.
- Online IDEs which include Unix/Linux terminals.
- Full-function Unix/Linux virtual environments in the cloud.

Standalone online Unix/Linux terminals. These terminals are often free of charge. They also are not necessarily based on a real OS kernel. A considerable part of standalone online terminals emulates the effect of some commands through JavaScript. However, other online Unix/Linux terminals are based on full emulators (e. g. QEMU), and thus give the user more realistic experience. *Examples:* JSLinux [11], Copy.sh Virtual x86 [12], Webminal [13], Linuxzoo [14] (based on full emulation), JS/UIX [15], Weblinux [16], Browsix [17], CB.VU [18] (simplified emulation).

The Table 1 gives a comparison of different standalone online Unix/Linux terminals.

The main advantage of standalone online Unix/Linux terminals is their easy accessibility. Among the disadvantages of these terminals are a limited set of commands available, obsolescence, limitations of root access and/or of network access. Furthermore, since most of standalone online Unix/Linux terminals appear to be projects developed and supported by few enthusiasts, there are some doubts about the future of these projects.

Online integrated development environments (IDEs) which include Unix/Linux terminals. These tools' main function is writing code. However, some online IDEs also include Linux terminal with programming commands installed. Some other online IDEs do not provide a terminal, but allow writing and running bash scripts. Root access and networking from the virtual environment are usually provided in paid online IDE services.

Examples: Codio [19], Cloud 9 [20], Codeanywhere [21], Paiza.io [22] etc. Among the advantages of online IDEs is multifunctionality and usually more recent Linux releases than in standalone online terminals. The disadvantages of these environments include a stronger focus on programming than on administrating causing that some components are not available.

Terms of use of free online IDEs may be changed. That was the case with Cloud9 IDE. Originally the service offered a virtual machine with Ubuntu Linux, full-function terminal and an IDE for collaborative programming for all the registered users. Later, due to numerous security violations from these virtual machines, the provider changed the terms. According to the new terms, users have to connect virtual machines from other services.

Full-function Unix/Linux virtual environments in the cloud. These environments are virtual machines or virtual containers in the cloud, usually with administrative rights and network available. Commonly such services conform to the IaaS model (Infrastructure as a Service). Some of the IaaS services offer a long free trial period and special programs for educational institutions. *Examples:* Amazon EC2 [23], Google Cloud Platform [24], Microsoft Azure [25]. The main advantage of the full-function Unix/Linux virtual environments in the cloud is access to most of OS commands,

including administrative and networking. The main disadvantage is that regular usage is non-free.

Table 1. Comparison of standalone online Unix/Linux terminals

Service name and developers	Virtualization / Guest OS	Options
JSLinux , Fabrice Bellard	Full emulator (compiled to JavaScript) / Linux 4.12.0 (Buildroot), Linux 4.15.0 (Buildroot, Fedora 29)	<i>Progress saving:</i> Yes, through VFSync <i>Networking:</i> Yes, bandwidth up to 40 kB/s, up to two connections per public IP address <i>Root privileges:</i> Yes <i>GUI:</i> Yes
CB.VU , Colin Barschel	Very simplified emulator (JavaScript) / None, emulates few Unix commands	<i>Progress saving:</i> No <i>Networking:</i> No, emulates few networking commands (e. g. ping) <i>Root privileges:</i> No <i>GUI:</i> No
JS/UIX , mass:werk, Norbert Landsteiner	Simplified emulator (JavaScript) / None, emulates limited number of Unix commands	<i>Progress saving:</i> Partially yes (demo version) <i>Networking:</i> No <i>Root privileges:</i> Yes <i>GUI:</i> No
Copy.sh Virtual x86 , Fabian Hemmer et al.	Full emulator (compiled to JavaScript) / ReactOS, FreeBSD 10.2, Oberon 2.3.6, Arch Linux, KolibriOS, Linux 2.6, Linux 3.18, OpenBSD, Solar OS; supports OS images, uploaded by a user	<i>Progress saving:</i> No <i>Networking:</i> Yes, in some cases (e. g. Linux 3.18) <i>Root privileges:</i> Yes <i>GUI:</i> Yes, in some cases (e. g. KolibriOS)
WebLinux , Rémi Sharrock	Simplified emulator (JavaScript) / None, emulates limited number of Unix commands	<i>Progress saving:</i> No <i>Networking:</i> No <i>Root privileges:</i> Yes <i>GUI:</i> No
Browsix , Bobby Powers, John Vilk, Emery D. Berger	Emulation of Unix abstractions through browser API (JavaScript)	<i>Progress saving:</i> No <i>Networking:</i> No <i>Root privileges:</i> No <i>GUI:</i> No
Webminal	Full emulator / Ubuntu Linux	<i>Progress saving:</i> Yes <i>Networking:</i> Yes, with restrictions <i>Root privileges:</i> Yes, in paid accounts <i>GUI:</i> Yes, in paid accounts
Linuxzoo , Gordon Russel	Full emulator (QEMU) / CentOS 7	<i>Progress saving:</i> No <i>Networking:</i> No <i>Root privileges:</i> Yes <i>GUI:</i> Yes, through Java VNC

3.4 The requirements for Linux online virtual environments for teaching the operating systems course

The analysis of free ready-made Linux online virtual environments currently available along with the analysis of an experience of teaching courses in operating systems showed the need for an individually designed system to provide Linux online virtual environments. The environments should meet the following requirements.

- **Realism.** Linux, virtualized through the environments, should behave the same way the real system would behave most of the time (throughout most of the practical assignments).
- **Relevancy.** The system should meet the requirements of the course.
- **Availability.** Virtual environments should be available to all the students attending the course after they had successfully proved their affiliation with the university.
- **Stability.** Failures need to be addressed properly and within a predictable time.
- **Scalability.** The system should be able to evolve for enabling new features or supporting larger hardware capacity. New features we are particularly interested in is the automation of simple assignments checking and grading (e. g. the correctness of commands used).
- **Security.** Security threats should be minimized. The effective mechanisms of dealing with potential security breaches need to be developed.

However, the listed requirements pose serious challenges that need to be overcome.

The challenge of a wide choice. There are different virtualization technologies and platforms that could be applied to complete the job. Analysing them and selection of an appropriate among a great variety of options is a resource demanding task.

The challenge of implementing. Design, development and support of the target system is another resource-demanding task.

The challenge of network isolation. The mentioned above problem of Internet access from inside the online Linux virtual environment is typical for all virtualized systems which are publicly available. Granting root/sudo access to students may produce serious security challenges. The problem is greatly exacerbated if network access is also provided.

The popular solution lies in making virtual environments isolated from the internet. Students may reach virtual terminals via the internet to input commands (e. g. through the web browser), but the internet access from within the virtual environment itself is forbidden. Such an approach is entirely appropriate for teaching the vast majority of Operating Systems course units, while it is inadequate for practising on network configuration or installing software from network repositories.

Another possible solution to the network access problem is getting real personal data of the online user, who works with virtualized OS remotely. Notably, cloud service providers, giving virtual machines in the cloud with both root access and networking available (Amazon Web Services, Google Cloud Platform, Microsoft Azure etc.),

affiliate user account with a valid credit card number. This does not guarantee the legitimate use of an account, but facilitate investigation of possible security violations.

The third solution lies in giving students limited network access within the online virtual environment (enough for testing network configuration). A local repository for learning commands like *apt* may also be organized.

The challenge of a “playground”. Conversely, another question arises: will the always-on system specially tailored for the learning needs be able to give students an experience of dealing with some problems real administrators may face? We find it crucial to find an optimal balance between stability and realism. Will such a “playground” environment be enough to motivate students to continue learning Linux after they finish the course? Given the foregoing, some assignments may be still done using less predictable tools like VirtualBox-based virtual machines. This affects some requirements for online Linux virtual environment. Namely, if certain assignments will be done outside the environment, then:

- a command-line interface may be enough for the online environment (even if the course include assignments on the Linux GUI);
- an implementation plan may start from isolated environments without the ability to reach the network from inside out, as long as these environments may be easier to manage on this stage.

The challenge of a transition. Besides the expenditure of resources on design, development and implementation of the system, the latter will imply a phase of transition. The transition from using tools described in subsection 3.2 to using online Linux virtual environments could be smoothed by applying additional tools, which need to be prepared in advance according to the varied approach mentioned earlier. These additional tools may include some previously used tools (e. g. locally installed hypervisors) as well as online Linux terminals (e. g. virtual machines from NDG Linux Essentials course, Webminal etc).

4 Conclusions

The work has made a survey on Linux online environments based on various virtualization technologies with the objective to elaborate the requirements to an individually designed system which provides such environments.

Linux ready-made online virtual environments are organized into three major groups: standalone online Unix/Linux terminals; online integrated development environments (IDEs) which include Unix/Linux terminals; full-function Unix/Linux virtual environments in the cloud. The main advantages and disadvantages of each group, as well as a comparison of standalone online Unix/Linux terminals, is done.

We also analyzed our previous and current teaching experience to find out online tools that proved efficient and the reasons why they still do not meet part of the course needs.

The study concluded the need for designing and implementing a virtual Linux environment with remote access to meet individual requirements of the Operating Systems course. The virtual Linux environment should be realistic (supporting most Linux commands through real execution, not imitation); relevant (meeting requirements of the course); available (accessible through the internet, for everyone who can prove his or her affiliation with the university); stable (failures should be addressed effectively); scalable (support increasing hardware capacity, be able to evolve); secured (security threats should be minimized, security breaches should be effectively handled). Another point of interest concerns the partly automation of practical assignments, including training and grading.

Future studies should focus on the investigation of virtualization technologies suitable for Linux online environment, including private open-source cloud platforms.

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Development and Using of a Virtual Laboratory to Study the Graph Algorithms for Bachelors of Software Engineering

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Abstract. The paper presents an analysis of the importance of studying graph algorithms, the reasons for the need to implement this project and its subsequent use. The existing analogues analysis is carried out, due to which a list of advantages and disadvantages is formed and taken into account in developing the virtual laboratory. A web application is created that clearly illustrates the work of graph algorithms, such as Depth-First Search, Dijkstra's Shortest Path, Floyd-Warshall, Kruskal Minimum Cost Spanning Tree Algorithm. A simple and user-friendly interface is developed and it is supported by all popular browsers. The software product is provided with user registration and authorization functions, chat communication, personal cabinet editing and viewing the statistics on web-application use. An additional condition is taken into account at the design stage, namely the flexibility of the architecture, which envisaged the possibility of easy expansion of an existing functionality. Virtual laboratory is used at Kryvyi Rih National University to training students of specialty 121 Software Engineering in the disciplines "Algorithms and Data Structures" and "Discrete Structures".

Keywords: Virtual laboratory, graph theory, graph algorithms, visualization, software engineering.

1 Introduction

The graphs theory is an important part of discrete mathematics and one of the components of a fundamental bachelor's degree in software engineering [1]. The graph theory is studied in higher educational institutions individually or as part of other disciplines [2, 3]. Analysis of educational programs [4] shows that the greatest attention is paid to the following elements of the graph theory practical application:

1. Overview of classical algorithms: breadth-first search (BFS) and depth-first search (DFS), finding the shortest paths and maximum flow, etc.
2. Solving typical tasks of practical nature (about telecommunication towers, color mapping, some logical tasks related to graphical representation of relations).

3. Determination of the main ways of applying graphs: the search for related components in communication networks; search for the shortest and cheapest routes in communication networks.
4. Construction of skeletal tree: search for the maximum flow for the transport network, which identifies the sources, drains and bandwidth of the ribs.
5. Graph isomorphism.
6. Finding cycle in a graph: the Hamiltonian cycle (the traveling salesman problem (TSP); Euler cycle (network capability control)).
7. Graph coloring (geographical map coloring, creating schedules of training, resource allocation, etc.).
8. Planar graph (printed electronic design on electrical circuits, transport solutions, etc.).
9. Finding the centers of a graph (vertices, the maximum distance from which to all other vertices of the graph is minimal).

The main goals of our project are the development of an online system that would provide a detailed visualization of an algorithm functioning; the possibility of using it as a demonstration material during lectures, use as a platform for performing independent work with an additional opportunity of textual communication with mentors (teachers) to facilitate the assimilation of new material and to speed up the search for answers to questions that arose during training.

According to the goals, we need to solve the following tasks:

1. Build a hierarchical model of actor systems.
2. Create library modules of graph algorithms.
3. Develop a module for their visualization.
4. Develop a web resource map.
5. Modify the system of web application classes.
6. Develop data structures.
7. Design a database model.
8. Design a visual interface.
9. Implement project software modules.

2 Analysis of existing developments

Studying graph algorithms is not possible without a visual demonstration. Virtual laboratories are able to visualize graphs and step-by-step execute the algorithms. Such virtual laboratories can be used by teachers during lectures, students during independent study of the material, the implementation of computational experiments and practical tasks. Not surprisingly, the development of graph visualization tools and algorithms is always given special attention.

One of the most interesting examples of such virtual laboratories is the “Date Structure Visualizations of the University of San Francisco” [5]. This resource, which can be seen in Figure 1 and Figure 2, positions itself as a web application of the University of San Francisco website which demonstrates the algorithms visually.

Data Structure Visualizations

About
Algorithms
F.A.Q
Known Bugs /
Feature Requests
Java Version
Flash Version
Create Your Own /
Source Code
Contact

David Galles
Computer Science
University of San
Francisco

Currently, we have visualizations for the following data structures and algorithms:

- **Basics**
 - Stack: Array Implementation
 - Stack: Linked List Implementation
 - Queues: Array Implementation
 - Queues: Linked List Implementation
 - Lists: Array Implementation (available in java version)
 - Lists: Linked List Implementation (available in java version)
- **Recursion**
 - Factorial
 - Reversing a String
 - N-Queens Problem
- **Indexing**
 - Binary and Linear Search (of sorted list)
 - Binary Search Trees
 - AVL Trees (Balanced binary search trees)
 - Red-Black Trees
 - Splay Trees
 - Open Hash Tables (Closed Addressing)
 - Closed Hash Tables (Open Addressing)
 - Closed Hash Tables, using buckets
 - Trie (Prefix Tree, 26-ary Tree)
 - Radix Tree (Compact Trie)
 - Ternary Search Tree (Trie with BST of children)
 - B Trees
 - B+ Trees
- **Sorting**
 - Comparison Sorting
 - Bubble Sort
 - Selection Sort
 - Insertion Sort
 - Shell Sort
 - Merge Sort
 - Quick Sort
 - Bucket Sort
 - Counting Sort

Fig. 1. The University of San Francisco web application

Depth-First Search

Start Vertex:

Directed Graph
 Undirected Graph
 Small Graph
 Large Graph
 Logical Representation
 Adjacency List Representation
 Adjacency Matrix Representation

Parent	Visited
0	f
1	f
2	f
3	f
4	f
5	f
6	f
7	f

Animation Completed

w: 1000 h: 500

Fig. 2. Algorithm demonstration

This web resource presents a wide variety of algorithms, among which: basics algorithms, recursive algorithms, indexing algorithms, sorting algorithms, heap-like data structures, graph algorithms, dynamic programming, geometric algorithms.

Particular attention is paid to the following graph algorithms: Breadth-First Search, Depth-First Search, Dijkstra's Shortest Path, Prim's Minimum Cost Spanning Tree,

Topological Sort (Using Indegree array and DFS), Floyd-Warshall (all pairs shortest paths), Kruskal Minimum Cost Spanning Tree Algorithm.

The main advantages of [5] can be considered:

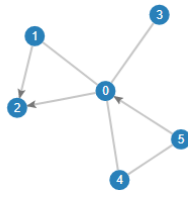
- Clear, not overloaded with interface elements.
- Convenient structured list of algorithms
- Sufficiently wide range of different algorithms.

Among disadvantages we can list the following:

- Outdated design of the pages, style is not pleasant to the eye.
- Absence of any textual description of algorithms.
- Presence only of English localization.
- The lack of returning option on the main page.

Another example of a web-based graph and graph visualization program is Greuler [6]. This resource (Fig. 3) positions itself as a web application that demonstrates the capabilities of the library which renders graphs and was created by Mauricio Popp.

Please take a look at all the methods of `instance.graph` which can be found [here](#)



```
var order = instance.graph.nodes.length;
var size = instance.graph.edges.length;

if (!order || size > 15) { return; }

var uIndex = Math.floor(Math.random() * order);
var vIndex = Math.floor(Math.random() * order);
var u = instance.graph.nodes[uIndex];
var v = instance.graph.nodes[vIndex];

var edge = { source: u.id, target: v.id };
// random edges have weight
if (Math.random() > 0.5) {
  edge.weight = Math.floor(Math.random() * 10);
}
// random edges are directed
Math.random() > 0.5 && (edge.directed = true);

// Adding an edge to the graph between some existing nodes
// in the graph
instance.graph.addEdge(edge);

// after the structure of the graph has been changed it's
// needed to trigger a new layout
instance.update();
```



Fig. 3. Demo page

The main advantages of [6] can be considered:

- Clear, not overloaded with interface elements.
- A clear and concise presentation of information.
- Intuitive interface.

Among disadvantages we can list the following:

- Absence of a list of algorithms.

- Presence only of English localization.

Based on given the advantages and disadvantages of existing programs, we decided to develop a virtual laboratory for studying graph algorithms that would satisfy the following requirements:

- a simple and adaptive web interface due to which it would be equally convenient to work on both desktop PCs and mobile devices;
- the ability to authorize users and provide control over student activity;
- support for multiple user roles;
- a demonstration of the basic graph algorithms, the study of which is provided by the training program for students of specialty 121 Software Engineering;
- Ukrainian-language localization, facilitating work with a virtual laboratory for students of Ukrainian universities;
- the ability of students to communicate with teachers and among themselves during laboratory work.

3 Results

The developed system should contain the following functions:

- (1) User authorization.
- (2) Providing users access to their personal profile.
- (3) Ability to flexibly edit user's personal data.
- (4) Sharing short text messages (chat).
- (5) Presence in the system of roles "Administrator", "Mentor", "Student", "Guest".
- (6) "Administrator" – a role in the system, which provides unlimited access to user profiles, ability to chat with them and overview the general statistics of the web application.
- (7) "Mentor" – a role in the system, envisaging the possibility of viewing the user profiles with a role of "Student", chat-communication with them and viewing their statistics of study graph algorithms presented in the system.
- (8) "Student" – a role in the system, envisaging the possibility of studying the graph algorithms represented in the system, and conducting chat-communication with the users with the role of "Mentor".
- (9) "Guest" – a role in a system that is automatically assigned to all unregistered users. It provides only the possibility of studying the graph algorithms represented in the system.
- (10) Availability in the system of visualization modules of such graph algorithms: "Depth-first search", "Dijkstra's algorithm", "Floyd-Warshall Algorithm" and "Kruskal's algorithm".
- (11) Maintaining statistics on the time spent by users with the role of "guest" on the study of algorithms.
- (12) Provide the system with a feedback module.

Technological requirements:

1. The server and client parts of the web application should not be dependent on the operating system or version of the operating system.
2. The web application must be compatible with browsers like Google Chrome, Opera, and Mozilla Firefox.
3. The server part should be developed using PHP (version 7) and MySQL (version not lower than 5.0).
4. When developing the system, you need to use a modular approach: the source texts must be divided into modules depending on the implemented functionality.
5. To build the user interface, the Model-View-Controller (MVC) approach should be used. The developer should not mix within one implementation file, responsible for building the interface and business logic.
6. User rights must be consolidated in one file, module or table, external, in relation to the functions themselves.

Non-functional requirements:

1. The system interface should be built to take into account the latest trends in web application development.
2. The interface should not be overloaded with visual elements.
3. The system should ensure the simultaneous operation of many users, without its rejection. It is allowed to increase the response time of the system.

Additional requirements:

1. To enhance the usability of the system, all features of the web interface of AJAX technology, where applicable, such as chat communication and graphical display of statistics, should be implemented without over-loading the page after each action.
2. The system should be developed “open” for change, with the submission of exclusive rights.

Figure 4 shows the main window of the program, on which the user is prompted to select an algorithm for study.

Figure 5 shows a page demonstrating one of the graph algorithms (Depth-first search). Working with a virtual laboratory, the user can use the prepared graphs or create a new arbitrary graph. The visual display of the graph is supported, as well as its presentation in the form of an adjacency matrix or adjacency list. It is possible to work with both oriented and non-oriented graphs. For most algorithms, such as graph search algorithms, it is possible to set a start vertex. Otherwise, the program will consider the initial vertex 0.

The visualization of the algorithm takes place in the form of an animation that can be viewed step-by-step or continuously. The user can adjust the animation speed independently.

An additional feature of the program is the display of theoretical information about the algorithm. To go to theoretical materials, you must click the Description button (Fig. 5).

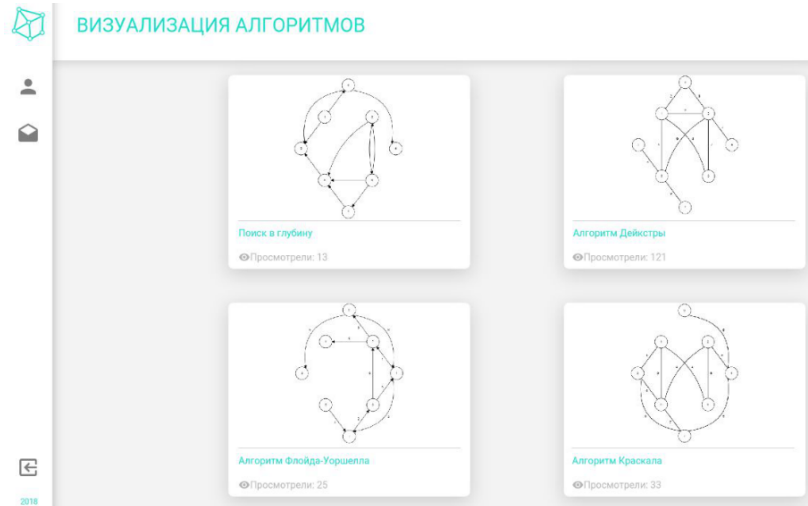


Fig. 4. The page for choosing an algorithm to study

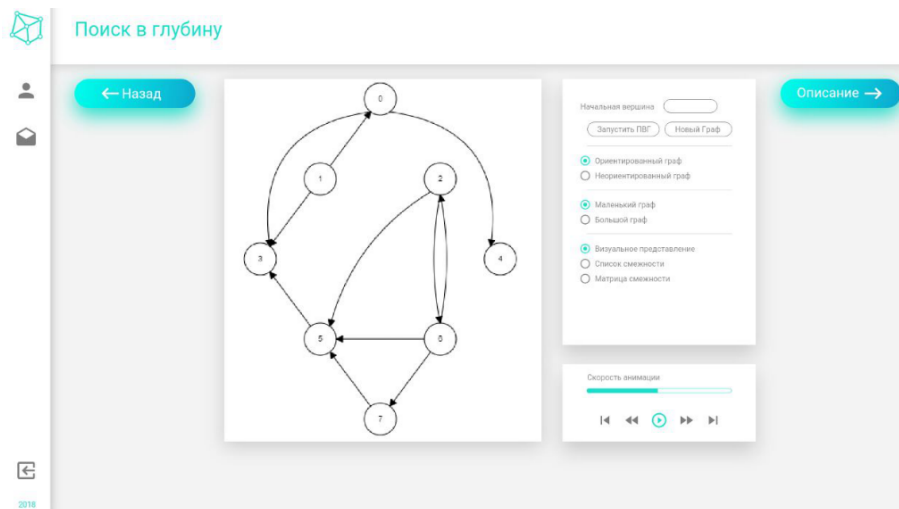


Fig. 5. Depth-First Search Algorithm Demo

The program records the activity of each student. For this purpose, a user profile is created (Fig. 6). The user can control the general data independently.

Authorized users have the opportunity to communicate in a special chat (Fig. 7). Virtual laboratory chat has primarily educational purpose. With its help, students can receive teacher advice, receive assignments or recommendations, and communicate with each other.

It should be noted that students of specialty 121 Software Engineering were involved in the development and testing of the virtual laboratory individual components. This provided them with the opportunity to gain practical experience in team work on

software products, as well as to deepen their own knowledge in the field of graph theory. A subsequent group of students continues to work with the program as users, studying graph algorithms and experimenting with them, as well as finalizing the program, developing new components, implementing additional algorithms, etc.

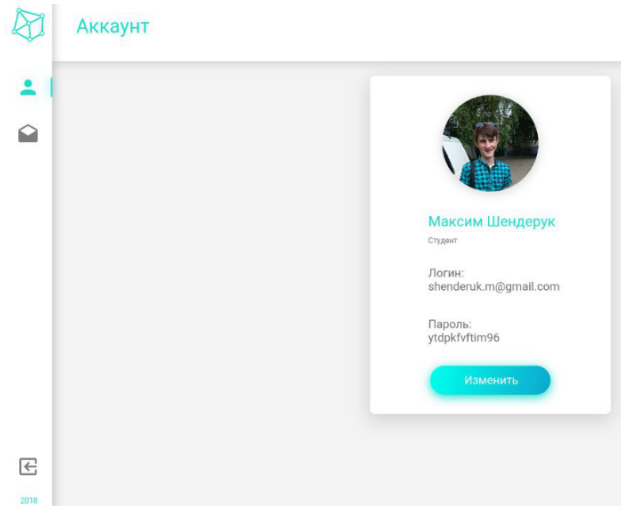


Fig. 6. Virtual laboratory user profile

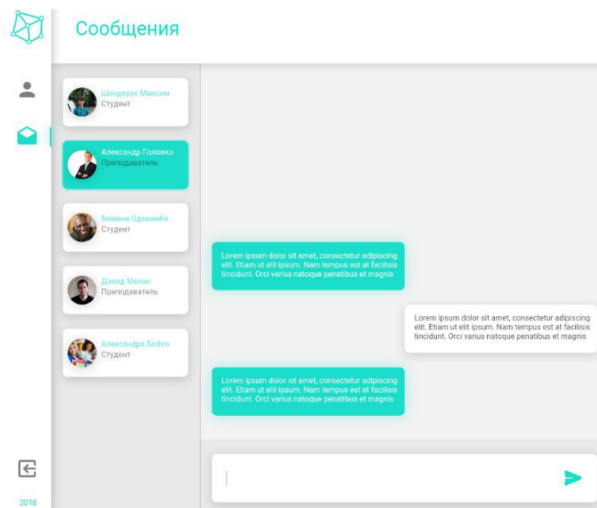


Fig. 7. Virtual laboratory chat

The simple and minimalistic interface of the virtual laboratory simplifies the work with it and provides the opportunity to adapt it for both desktop and mobile devices. This program feature creates the conditions for its effective use in the mobile training of software engineers [7; 8].

Today, a virtual laboratory is used at Kryvyi Rih National University to training students of specialty 121 Software Engineering in the disciplines “Algorithms and Data Structures” and “Discrete Structures”. The development of additional components is included in the topics of qualification work of bachelors in software engineering.

4 Conclusions

The precedence diagrams, class diagrams, and flowcharts and site interface were created in the process of designing a software product. Programming technologies and database architecture were selected during the development. The most important modules of the software complex and the typical scenario of its use were considered.

The following series of tasks are successfully completed:

1. A web application is created that clearly illustrates the work of graph algorithms.
2. A simple and user-friendly interface is developed and it is supported by all popular browsers.
3. The software product is provided with the function of user registration and authorization, chat communication, personal cabinet editing and viewing the statistics on web-application use.
4. A reliable user data protection system is developed. The security system is based on modern data encryption technology.

An additional condition was taken into account at the design stage, namely the flexibility of the architecture, which envisaged the possibility of easy expansion of an existing functionality.

The software package has been tested and is fully ready for further use.

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Virtual Chemical Laboratories as a Tools of Supporting the Learning Research Activity of Students in Chemistry While Studying the Topic “Solutions”

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Abstract. The article discusses the importance of student research activities for the effective formation of the key competencies of a future specialist in the field of chemistry. The theme “Solutions” is defined as one of the most important in the school chemistry course and at the same time as the most suitable for the implementation of educational research activity of students. To support students’ research activities, two types of virtual chemical laboratories are used: distance and imitation. The combination of these types of virtual chemical laboratories in the study of the topic “Solutions” provides an opportunity to take advantage of each of them and increase the level of support for educational and research activities of students. The conditions and ways of using virtual chemical laboratories to provide students with research activities when studying the topic “Solutions” are examined. Examples of developed virtual chemical works and their essence are given. Based on the implementation of virtual chemical laboratories in the educational process of various educational institutions, it is justified the assumption about the effectiveness of using the developed virtual chemical research to develop students’ research activities when studying the topic “Solutions”.

Keywords: Solutions, Learning Research Activity, Virtual Chemical Laboratories.

1 Introduction

The modern educational process is impossible to imagine without using the innovative technologies. Education, like the other spheres of human activity, is on the way to the information stage of society.

For the effective activity in the modern society, a person must be able to search, process and interpret data, because their number is huge and increases every year; understand the mechanisms of obtaining these data and conclusions from them, critically assess their reliability and importance; be able to carry out activities related to obtaining new data and the desire for learning and self-improvement throughout life.

The formation of the listed skills is most effectively carried out in the process of learning research activities of students.

Learning research activity in chemistry involves significant waste of chemical reagents and time, the need for chemical utensils and specific equipment, the risk to the health of students and teachers, and so on. These features of learning research activities in chemistry are not the disadvantages but they to some extent hinder its implementation in the educational process of most schools.

Virtual laboratories, in our opinion, have the significant potential as a tools of resolving the contradiction between the need for the widest possible implementation of research activities in the learning process and the action of factors hindering this implementation, helping to involve all participants in the active research activities, encouraging students to self-expression and self-realization, developing critical and associative thinking, imagination, ability to analyze, give examples, defend their own thoughts.

2 Development of students' learning research skills while studying the topic "Solutions"

The educational institution must prepare a student who thinks creatively, has theoretical and fundamental knowledge, appropriate skills for the independent work and the ability to process and explain the results of their research.

One of the most important competencies that students acquire in the learning process is research competence – it is the formed quality of personality, which is expressed in the mastery of knowledge, skills and methods for the effective research and the ability of independently acquire new knowledge [7].

The formation of pupils' research competence takes place in the process of independent creative research activity and is a necessary condition for the professional development and self-improvement of the individual. Learning research activity is practically the only means for the formation and development of research competencies.

Modern specialized education should initiate and develop the individual's ability to carry out research activities, higher education institutions – to consolidate and deep these skills, as well as bring them to the highest level – the ability to conduct independent research.

Thus, research skills should be formed in school, which takes place in the form of the learning research activities. This is done by involving students to the implementation of the educational research, projects, introduction to the educational process the elements of research activities.

Independent acquisition of new knowledge about the environment is the purpose of learning research activities, in contrast to the usual educational activities (explanatory and illustrative) [9].

We are most impressed by the opinion of Tatiana V. Nefedova, who interprets the research activities of pupils' as "the process of solving a creative problem that does not

have the result, based on mastering the features of the environment through the scientific methods, during which the translation of cultural values” [10].

Therefore, the research is characterized by an active cognitive position which is based on the internal search for answers to any question, through comprehension and creative processing of data, action through “trial and error”, the activation of critical thinking.

The work on the formation of research skills in chemistry lessons can be divided into four interrelated areas:

1. inclusion of research elements in the structure of the lesson while studying new material;
2. organization of laboratory and practical work as research, which will provide an opportunity to increase the level of interest of students in obtaining and interpreting the results of these works;
3. formulation of homework in the form of research can diversify this form of activity and make it more interesting;
4. planning and conducting extracurricular activities (research group, project work), using tasks with active research activities [13].

The current state of the most schools in Ukraine does not allow students to carry out research activities on a large scale – covering the whole classes, and is implemented, as a rule, only with children in the category of “gifted” and, mainly, in the form of extracurricular activities.

Solutions is the most common objects of pupils’ research in chemistry. Because the solutions surround a person in nature, everyday life, industry and other areas of activity, students get acquainted with them in childhood. In the course “Natural Science” (5th grade) this acquaintance is more substantive and scientific. Solutions become the main object of study and research in the 9th grade during the study of the relevant topic in the course of chemistry [5].

The chemistry curriculum [5] in 9th grade provides for solving experimental problems at this topic, as well as the equations of reactions using solutions with a certain mass fraction of solute; using of demonstration experiments, laboratory experiments, practical work, preparation and defense of educational projects.

Most of these forms of activity directly or indirectly contribute to the development and improvement of learning research skills of pupils. However, it should be noted that a number of planned laboratory experiments and practical work will be performed in an abbreviated or demonstration form. If we talk about the development of research skills of students, then there is a need for additional chemical experiments, which aim to reveal the essence of the phenomena studied, to provide pupils with a creative approach to solving research problems, to consolidate theoretical knowledge through multiple empirical confirmation.

The most important and most complex semantic parts of this topic are the solubility of substances, its dependence on various factors; saturated and unsaturated, concentrated and diluted solutions; thermal phenomena accompanying the dissolution of substances; the concept of crystal hydrates; electrolytic dissociation. Therefore, the

learning research activities should be directed to the study of these semantic parts of the topic.

The topic “Solutions” is the central in the study of chemistry, because it is intertwined with important sections of inorganic and organic chemistry, chemical technology; the processes of dissociation, ion exchange reactions and other types of reactions are also somehow related to this topic.

The prevalence and availability of solutions also makes them as the unique object for pupils’ learning research activities. A significant number of classes at this topic can be organized in the form of educational research, both laboratory and home (applied).

While studying the topic “Solutions”, students acquire skills in working with chemicals, chemical equipment (including measuring equipment), the ability to observe, measure, calculate. At the same time, learning research activities provide an opportunity to do this at a better level, while developing the ability to make assumptions, build algorithms for testing them, conduct experiments and formulate conclusions.

The problems of effective organization of the learning research activities of students while studying the topic “Solutions” are:

- insufficient time to conduct a large number of different learning experiments (especially long-term);
- imperfections in the material support of school chemical laboratories (lack of scientific equipment, potentially dangerous substances and precursors, insufficient number of utensils, etc.);
- limitations related to the physical abilities and health of individual students, features of psychical and mental development, cognitive activity, etc.

3 Virtual chemical laboratories as a tools of teaching chemistry

In many cases, the equipment of the chemical cabinet does not provide an opportunity to carry out full-fledged practical work in the format of “one set of reagents and equipment on the desk”, both due to overcrowding and lack of appropriate sets. Although this problem is ignored by most teachers and methodologists of chemistry, it still exists in the last few decades and significantly worsens the state of science and mathematics education in general, and chemical education in particular.

That is why a good option to overcome the listed problems is using the electronic learning tools in the educational process, namely virtual chemical laboratories (VCL).

Usually virtual laboratories are divided into two types:

- laboratory installation that provides remote access [6];
- software in which all processes are modeled using a computer that allows you to simulate laboratory experiments – virtual laboratories (in the narrow sense) [11].

Thus, we can distinguish two types of virtual laboratories: remote and simulation.

Remote virtual chemical labs provide remote access to real lab equipment either in real time or by playing relevant videos. The remote virtual laboratory includes:

1. a real laboratory with real equipment and reagents;
2. software and hardware for control of the corresponding equipment and digitization of the received data;
3. tools of communication to connect users with the first two components.

Virtual laboratories, in which the relevant equipment, substances and processes are modeled using a computer or other gadgets, are a set of programs designed to simulate laboratory work in the laboratory [11]. Simulation virtual chemical laboratories can be represented by a set of immutable models, as well as mathematical interactive models that can adequately reflect the effects of various user actions associated with changes in the conditions of the experiment, in its results. The main advantage of such virtual chemical laboratories is the ability to implement a creative approach to the implementation of virtual experiments by users and the formation of users a more holistic view of the simulated processes and phenomena.

Both types of VCL have common advantages:

1. no need to purchase expensive equipment and reagents;
2. no risk to the life and health of students associated with real experiments, especially if they use toxic or corrosive substances, flammable materials, electrical appliances, etc.;
3. translation of the results into electronic format, which saves time and resources associated with the need to re-measure, record, verify the accuracy of the data;
4. the possibility of using a VCL for distance and inclusive education, which consists in organizing laboratory work even in the absence of access to school laboratories, for example when working with children with limited physical abilities who miss classes due to illness or under quarantine time.

At the same time, VCL of any type are the only models of the real world, and, like all other models, they have a certain limitation in the reflection of reality – the model reflects only the most significant features of the object of study, ignoring the secondary.

Simulation virtual laboratories have the advantage over remote ones in the ability to change the experimental conditions many times and perform all the experimental operations almost instantly (saving time), the advantage of remote virtual laboratories is a more realistic reproduction of all details of the experiment.

Virtual chemical laboratories can transmit learning content in two ways:

1. placement on local devices and digital media;
2. placement on sites on the Internet.

In modern VCL, experiments are based on a mathematical model of a real chemical process, that is the possibility of changing the conditions of the experiment within certain limits and adequately reflect these changes in its results. This approach should promote pupils' independent research of the world and enable teachers to realize their creative abilities in the process of teaching chemistry. The development of such simulation virtual chemical laboratories with a mathematical model at the core is, of course, more complex and time-consuming, but in turn it significantly expands the

possibilities of their application [3]. Examples of such virtual chemical laboratories are Yenka Chemistry [12], Model ChemLab [8] and VirtualLab (VLab) [1].

When creating VLab, the developers from ChemCollective aimed to create interactive learning environments that would be flexible and allow students to get closer to chemistry, trying on the role of practicing chemists [3].

ChemCollective Virtual Lab software currently covers more than 50 exercises and tasks that help in mastering chemical concepts, mainly related to the study of solutions and the processes that take place in them [2].

Having analyzed the technical and visual capabilities of the VCL Virtual Lab, we concluded that the support of teaching and research activities of students in chemistry with its participation can be provided by creating virtual experimental problems related to various aspects of dissolution processes: dissociation of substances in solution, change of pH, energy and quantitative characteristics of the dissolution process, as well as the use of some qualitative reactions, indicators, etc.

Laboratory work related to the study of the properties of colloidal solutions, the course of some exchange reactions, crystal obtaining, research of analytical effects of qualitative reactions associated with the formation of sediments, can not be implemented in this VCL due to limited possibilities of modeling chemical phenomena in Virtual Lab visual support (for example, there are not enough test tubes among the equipment to carry out qualitative reactions with the formation of sediment, and the presence of sediment and its color become visible in glasses on the virtual laboratory desktop only in quantities of a few grams or more, which does not comply with qualitative chemical analysis) [4].

On the other hand, the use of remote virtual laboratories provides an opportunity to observe high-quality visualization of relevant processes occurring with real objects – it is possible to conduct high-quality chemical experiments and perform practical work or experimental tasks of a qualitative nature. However, this type of virtual laboratories, at least those that are publicly available, do not provide the opportunity to interfere in the process and perform quantitative experiments.

Remote virtual laboratories should be used in the same types of lessons as other virtual chemical laboratories: at the stage of learning or consolidating new material, as independent or home research, in classes of relevant electives or groups, and to test students' knowledge (in the form of experimental tasks).

Thus, in our opinion, it is possible to qualitatively support the learning research activities of chemistry students in the study of the topic "Solutions" by combining the capabilities of two types of virtual chemical laboratories – remote (for qualitative experiments) and simulation (for quantitative experiments).

In both cases, there is a need to develop their own laboratory works, which will be implemented through virtual chemical laboratories and will be adapted to the content of the curriculum for secondary schools in chemistry (topic "Solutions", grade 9).

4 Creation and testing of a set of virtual laboratory works for the organization of learning research activities of pupils in chemistry in the study of the topic “Solutions”

We have created a set of experimental problems on the topic “Solutions”, which contains seven tasks: “Preparation of sea water”, “Preparation of saturated solutions of various chemical compounds”, “Precursor”, “Dilution of solutions”, “Separation of a mixture of salts”, “Preparation of solution magnesium sulfate”, “Thermal effects of dissolution”. The process of their development and implementation is described in detail in [9]. Most of the tasks in the set developed for the topic “Solutions” are formulated in a research (problem) style – the student has a task:

1. to obtain a certain practical result;
2. to study processes and phenomena, the exact properties of which are unknown to him in advance.

In the first case, the student has the opportunity to create their own algorithms and check their adequacy in practice, but in a virtual environment. The use of trial and error method is not ruled out. In the second case, completing the task will mean for the student the discovery of subjectively new patterns, properties, and so on. That is why, the student has the opportunity to independently, based on the results obtained in the VCL, to draw conclusions about the influence of the certain factors on the dissolution process, and only then compare them with those in textbooks described, heard from the teacher’s story, etc.

Most of the tasks contain enough prompts for the student to experiment in a virtual laboratory on their own, for example, at a home computer, and some of the tasks can be reproduced in a real educational chemical laboratory of the school if time and opportunity (in this case the task in the virtual laboratory can be used as a training option to check the correctness of theoretical calculations and repeat the order of necessary actions).

The VLab VCL provides the possibility of independent repeated experimentation with various substances and their solutions, with the involvement of accurate measuring instruments, but it is not designed to perform qualitative reactions. Most qualitative reactions do not require accurate calculations and measurements, but they do require as clear an analytical effect as possible, not distorted by the imperfection of the object’s appearance in its model. For the virtualization of qualitative experiments, qualitative visualization is often more desirable than the ability to make accurate measurements. Since in the topic “Solutions” a certain amount of student research is related to qualitative chemical experiments (performing qualitative reactions, determining the acidity of the environment using indicators, etc.), there is a need to create a resource to support of qualitative chemical experiments. The most realistic transmission of visual information about an object is a video recording. The essence of the developed remote VCL is to provide users with remote access to a set of substances that can be used to perform high-quality laboratory experiments. At the same time, we tried to anticipate various options for user actions, including those that could have been done accidentally,

without logical justification. To do this, the program interface is organized in such a way that the user has two sets of reagents. Any reagent from the first set can be mixed with any reagent from the second. Selecting the appropriate pair of reagents triggers a short video recording of the mixing of these reagents in a real chemical laboratory. The user can not change the number of reagents or the order of their addition, but has the opportunity many times to observe high-quality visualization, accompanied by a textual description of the nature of the reaction that occurs.

The availability of such a VCL can be ensured by placing it on the Internet on the pages of the site. The window interface of such a remote VCL is essentially the html-page of the site. For the operation of a laboratory installation with remote access, it is necessary that the site page contains a set of elements of java script, video, codes, etc. that relate to a separate laboratory work (Fig. 1).

Имя	Размер	Изменено	Права	Владел...
..				
favicons		09.11.2019 18:04:40	rw-rw-r-x	249918
js		18.11.2019 23:04:21	rw-rw-r-x	249918
scss		09.11.2019 18:04:50	rw-rw-r-x	249918
videos		18.11.2019 21:46:07	rw-rw-r-x	249918
index.html	4 KB	19.11.2019 11:37:55	rw-rw-r--	249918

Fig. 1. Elements of the site of the laboratory installation with remote access.

The operation of the remote VCL created by us is provided by a number of objects located in different directories:

- the *favicons* folder contains favicon elements, i.e. site icons for different browsers;
- *js* folder is a folder for saving java script files that provide dynamic interactivity on the site;
- *scss* folder contains style files that form the external design and stylization of the site page;
- all videos of the experiments that we recorded for running on the site are saved in the *videos* folder.
- the *index* file is the main one, because the main startup code of the laboratory is written in it.

The following online page of the VCL involves the execution of certain program code, which can be edited by Notepad++ or xml-editor and uploaded to an FTP server.

The general principle of the first virtual laboratory with remote access on the topic “Indicators” is to select buttons from the upper left corner – the indicator, and the lower left corner of the solution with a certain level of acidity, such a combination of pressing

“Show” allows you to run videos where the first reaction, change of color of solution is shown (Fig. 2).

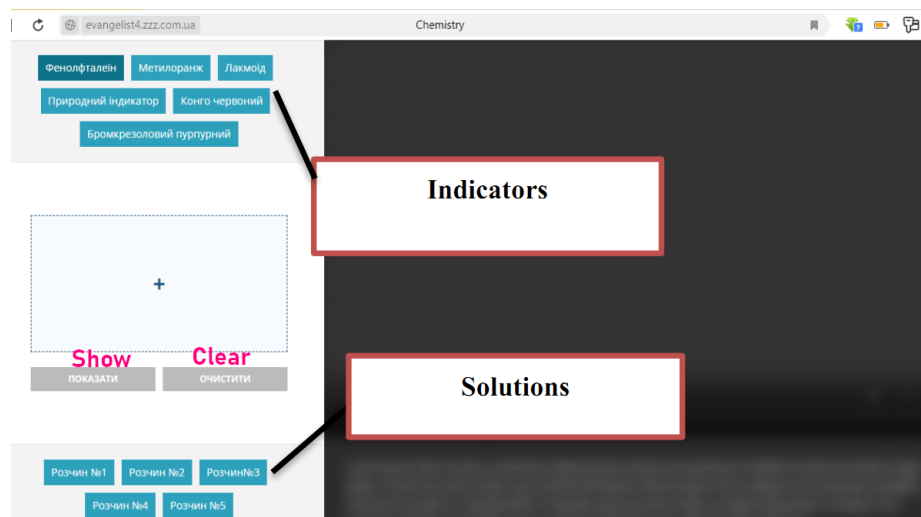


Fig. 2. Location of the buttons of the main elements of the remote laboratory

To return to the indicator and solution selection, press the “Clear” button in the middle on the left and start the selection again.

The following laboratory work No 2, created on the basis of the site, is based on an experimental problem on “Qualitative reactions to the most common anions.” The general principle of operation is similar to the VCL “Indicators” and consists in selecting the buttons from the upper left corner – solutions of reagents AgNO_3 , $\text{Pb}(\text{NO}_3)_2$, BaCl_2 , and the lower left corner – a solution containing an unknown anion to be determined by students. When you press the “show” button, a video is launched, which shows the course of the chemical reaction between the selected solutions.

It should be noted that both laboratory works can be used as research: the work “Indicators” contains not only the indicators described in the textbook, but also non-standard for the school curriculum – bromocresol purple, Congo red, red cabbage juice, and therefore work with them is easy to organize as a research. The work “Qualitative reactions of some anions” is generally an experimental task for the recognition of anions.

Both laboratory works are available at website of Olga O. Evangelist by links <http://evangelist4.zzz.com.ua/lab1/> and <http://evangelist4.zzz.com.ua/lab2/>.

The created virtual laboratory works were tested during chemistry lessons and optional classes in several educational institutions of the city of Kryvyi Rih during 2019: Kryvyi Rih Central City Lyceum, Kryvyi Rih Central City Gymnasium, schools No 66, No 21 and Kryvyi Rih College of National Aviation University of Ukraine. To do this, teachers used personal computers and netbooks, SMART Board interactive whiteboards, and smartphones and tablets.

Chemistry teachers especially noted the convenience of using virtual chemical laboratories to prepare for laboratory work or their partial replacement, and to organize effective independent work of students.

Students were asked a questionnaire with the following questions:

1. Were you interested in using virtual chemical laboratories?
2. Was it easy for you to use virtual chemical laboratories?
3. Will virtual experiments help you better understand the theoretical material of the topic?
4. Did virtual chemistry labs help you better prepare for classroom practice work?
5. What did you like most about using virtual chemistry labs while studying chemistry?

144 pupils took part in the survey. The results of the survey are shown in table 1.

Table 1. The results of survey

Number of question	Answers to questions				
	“No”	“Rather no”	“Hard to say”	“Rather yes”	“Yes”
1	0	0	11 (7,6%)	52 (36,1%)	81 (56,3%)
2	0	3 (2,1%)	18 (12,5%)	56 (38,9%)	67 (46,5%)
3	0	6 (4,2%)	14 (9,7%)	45 (31,2%)	79 (54,9%)
4	0	4 (2,8%)	13 (9%)	38 (26,4%)	89 (61,8%)

The fifth question with an open answer was often answered by students, which can be formulated as: “non-standard approach to the organization of lessons”, “unusual and novelty of the use of virtual chemical laboratories”, “the possibility to make experiments without time or strict responsibility for the quality of individual actions”, “the possibility to independently make experiments as you want or interesting”, “the possibility to prepare at home, especially if you missed the lesson”. According to the observations of teachers involved in the experiment, the use of virtual chemistry laboratories increased students’ desire to experiment and reduced their fear of making mistakes during the experiment, making erroneous conclusions, and so on. This was evidenced by the high results demonstrated by students in performing practical work and experimental tasks within the topic “Solutions”. Thus, the majority of students noted the positive effect of using VCL to acquire theoretical knowledge and prepare for practical work, and for the vast majority of VCL students were an interesting and easy to use tool for learning chemistry.

5 Conclusions

The learning research activities are an integral part of a quality educational process, especially in the study of natural sciences (chemistry, physics, biology, geography). The learning research activity differs from ordinary learning in that it requires an active cognitive position based on the internal search for answers to any question related to the understanding and creative processing of information, action through “trial and

error”, and from scientific research it differs, first of all, in the results – the acquisition of subjectively new knowledge, the formation of research skills and other personality traits of students.

One of the most important and integral topics in the school course of chemistry is the topic “Solutions” – while studying this topic, students consolidate knowledge of general and inorganic chemistry, acquire skills to perform experiments, gain theoretical and practical basis for further study of chemistry.

Virtual chemical laboratories are, first of all, unique simulators – tools that allow users to test the algorithm of actions, to trace the logic of certain laboratory operations during the experiment, to practice skills of collecting and recording the necessary data, experimental results and more. Remote virtual chemical laboratories have the advantage of conducting qualitative experiments, and simulation VCL – quantitative chemical experiments.

Virtual chemical laboratories in some cases can be used as a replacement for a real chemical experiment, if for some reason it’s implementation is impossible.

Virtual chemical laboratories provide an opportunity to safely and economically implement the development of research competencies of pupils through the use of experimental chemical tasks, which can be performed entirely in virtual mode or in simulator mode with subsequent implementation in the form of a naturally experiment.

Virtual chemical laboratories are a rather labile learning tool that can be used at almost any stage of the lesson: at the beginning, at the stage of learning new knowledge, at the stage of consolidation of knowledge and at the stage of testing, as well as for independent and homework. In the case of proper organization of work with them, the student has the opportunity to perform learning research at any time and in any place.

The created virtual laboratory works were introduced into the educational process of several educational institutions in Kryvyi Rih during 2019 and received mostly positive feedback from both chemistry teachers and students. This makes it possible to say that virtual chemical laboratories have a high potential for organizing and improving the learning research activities of students in chemistry while studying the topic “Solutions”.

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Demand and Learning Environment to Provide English-Language Learning at Technical Universities in Ukraine

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Abstract. The paper aimed to study the readiness of the existing e-learning environment for the organisation of English-language learning among Ukrainian and international students on the example of a technical university in Ukraine. The need for English-language training was explored by interviewing students with keen interest, level of English proficiency, motivation, preferred forms of learning, and a willingness to incur additional costs for such learning. About two-thirds of those surveyed showed interest in English-language education. About one-third of the students surveyed have the necessary level of preparation and are also prepared for additional financial expenses. About one-third of the students may also join English-language studies if they fulfil specific prerequisites. Expected employment progress is the primary motivation for joining the English-language program. The readiness of the existing learning environment was tested by analysing the organisation of access to English-language teaching materials, assessing the demand for different electronic resources, as well as the ability to take into account the learning styles of potential Ukrainian and international students in the educational process.

Keywords: Electronic Learning Environment, English-Language Learning; Learning Style

1 Introduction

Learning environments imply any places where students strive for their academic goals. Therefore, this term includes teaching strategies and methods, learning technology and resources, means of teaching, including technical aids, modes of learning, and connections to societal and global contexts [1-3]. In other words, the learning environment represents the current spatial, temporal and social learning situation. The term also includes the relevant cultural context and human behavioural and cultural dimensions, including the vital role of emotion in learning. Therefore, the learning environment consists of both human practices and material systems. The situation is similar to ecology, which is usually considered as a combination of living things and the physical environment [4].

Currently, learning environments have extended from the physical to the virtual and mobile due to the extensive use of information communication technologies (ICT) and the Internet which both transformed learning and teaching in the academic world [5-9]. The implementing ICT activity is expanding from the enhancement of learning, as was at the first stage, to the involvement in a learning process of completely new factors. They are not reduced to hardware, software, and the network. The use of ICTs can improve the quality of education by increasing motivation and engagement of learners, facilitating the acquisition of basic skills and enhancing teacher training [10, 11]. ICTs can promote the shift to a learner-centred environment, which is today the primary benchmark for changing the learning paradigm.

The main goal of institutions of higher education (IHE) is to provide high-quality training of future specialists. At Kyiv National University of Technologies and Design (KNUTD), the management system for IHE (MS-IHE), integrated with a quality management system (QMS), manages various aspects of daily educational activity [12-14]. Such integration simplifies planning, allocating resources, identifying new goals, and evaluating the overall performance of the institution.

In turn, the QMS is based on the automated control system (ACS), which was developed to manage data flows and control automation of all processes occurring at KNUTD. The objects of the QMS are the main components of scholarly activity: resources, educational processes and their outcomes

The ACS includes a few subsystems. In particular, the modular environment of the educational process (MEEP) is functioning at the KNUTD [12, 13]. The MEEP provides all necessary teaching and methodological support of the educational activities. It is realised an object-oriented dynamic learning environment on the base of the free learning platform for the organisation of distance education Moodle. The Moodle is the most common LMS for the organisation of e-learning in universities of Ukraine [15, 16].

The MEEP, operating at KNUTD, has been developed and optimised for use in the Ukrainian-language environment. At the same time, there are new challenges associated with changing the paradigm of the learning organisation. The main focus of the day is on student-centred learning. In other words, this means maximum consideration of the wishes or requirements of all stakeholders such as clients of the service (students) and customers of the graduates (employers).

One such requirement is the growing demand for English language training. Today, however, virtually none of the country's national universities has well-developed English-language educational programs, except for some narrow medical and technical fields [17, 18]. There is a potential demand for this type of educational services both among Ukrainian-speaking and English-speaking populations.

The trend of increasing demand for English-language education is familiar to many countries in the world [19, 20]. In 2002, EU universities offered 560 master's programs taught in English. As of June 2013, there were 6407 programs [21]. That is an increase of more than ten times compared to 2002 and 38% more than in 2011. The undisputed leadership here belongs to the Netherlands, Germany and Sweden. As for the disciplinary distribution of these programs, the clear leaders are English-language masters programs in business and economics (28%) and engineering (21%) [21].

The lack of English-language education programs also contributes to the outflow of Ukrainian students to study abroad. In the period 2013-2017 the number of Ukrainian citizens in the Polish universities tripled, in Spain, Italy and Canada doubled, and in the Czech Republic, Austria and the United Kingdom increased by 41% [21].

Besides, students from other countries may be interested in receiving English language education in Ukraine. For example, about 52% of Asian students are educated abroad. Students from China, India, Korea (up to 77% of the total number of such students) are on top of that [21]. Of course, if English-language education programs were introduced, a significant percentage of the immigrants from these countries would choose our IHEs, given their economic attractiveness.

There is also a demand for English-language teaching services from both international and Ukrainian students [22, 23]. All they would like to expand their prospects for further study abroad or employment. However, the question arises as to whether the existing learning environment responds to the new challenge? There is also little information about the students' current concerns about organising English-language training. The purpose of this paper was to investigate the compliance of the existing learning environment at KNUTD with the modern requirements and wishes of stakeholders in the provision of English-language training.

The paper goal is achieved by solving the following research problems: i) investigation of students' real demand concerning English-language learning, ii) identification of the problematic areas in the existing e-learning environment, and iii) exploration of how the existing system can be adapted to provide English-language learning.

The first task will be solved by conducting a survey of Ukrainian university students and analysing the results obtained in terms of distribution by years of study, faculties and forms of study.

Besides, the question remains how easily the existing learning environment can be adapted to the needs of English-language learning. First of all, this issue concerns the organisation of learner-centred learning, as well as the provision of students with English-language teaching materials.

Friendliness of the existing learning environment to the personal characteristics of students and openness to the adaptation will be clarified by studying the preferred learning styles of Ukrainian and international students. The supply of English-language textbooks to the library is limited primarily for economic reasons. Therefore, the use of e-resources (lecture notes, presentations, study guides, etc.) and the organisation of their access through the learning environment is a top priority.

2 Methods and materials

2.1 Survey methodology

In total, 1414 students of the first-to-fourth courses of six faculties of KNUTD were interviewed. First-year students enrolled at the university in 2019, 4-year students – in

2016. The distributions of respondents by Faculties together with Faculties' names (including abbreviations) and courses of study are given in Table 1.

Table 1. Number of students who participated in the survey

Faculties / Course	1	2	3	4	Total
Design (D)	82	70	63	85	300
Economics & Business (EB)	134	48	65	116	363
Fashion Industry (FI)	26	41	57	68	192
Mechatronics & Computer Technologies (MCT)	61	19	42	57	179
Entrepreneurship & Law (EL)	71	22	17	22	132
Chemical & Biopharmaceutical Technologies (CBT)	47	42	72	87	248
Total	421	242	316	435	1414

The purpose of the survey was to identify the attitude of students to the opportunity to undergo English-language training at KNUTD, depending on their age and field of study. All questions of the questionnaire were divided into five clusters and concerned the following topics:

1. identification of students (gender, faculty, course and form of study);
2. financial support (assessment of current financial status and availability of scholarships and additional sources of funding);
3. level of command of a foreign language;
4. motivation to take part in English-language learning, and
5. foreign language skills and English-language learning preferences, including financial aspects. The last block of questions was the most extensive and essential, as it allowed ones to assess students' existing needs for English language training.

The data obtained will be presented in relative units (percentages) to neutralise the potential impact of different numbers of students on faculties or courses. The number of students in any sample will generally be attributed to the total number of students studying English. When studying a graduate school, the number of students, who have expressed an interest in postgraduate studies will be used as a benchmark.

2.2 The methodology of testing of existing electronic learning environment

The most important details of the MEEP functioning at the KNUTD in the context of the considered problems are as follows. Lecturers create electronic teaching and learning complexes (ETLC) of all disciplines to fill the MEEP with necessary information. An ETLC can include a syllabus and scheduled work program of a subject. Also, it contains electronic textbooks, lecture notes, study guides and various tutorials. They can be presentations, dedicated videos, dictionaries and glossaries, reference books, etc. Similar systems were frequently described in the literature [11, 24].

The improvement of the quality of educational activities of the university is the main advantage of the implemented MEEP. Maintenance of permanent

communication between participants of the educational process demonstrates the effectiveness of MEEP use for all forms of learning. Teachers and students can communicate in a web-classroom environment with tutors, supervisors, an administrator-consultant and other members of the group through an online-chat or offline-email. Such tools as graphic chat, forum, bulletin board, testing, etc. are also actively used.

The existing learning environment allows the use of e-learning resources. However, these resources are known to be sensitive to personality traits. They may, therefore, be useful for some students and ineffective for others. Such a situation is best reflected by the known correlations between students' learning styles and attitudes towards e-learning resources or progress in studies [25]. The introduction of English-language learning, including the training of international students, actualises the issue of preferred learning styles among students of different groups.

Therefore, the differences in the learning styles are analysed for students of different specialities and nationalities studying at KNUTD. The preferred styles of Ukrainian students of some specialities are compared between each other, as well as with the learning preferences of Chinese students. Chinese students are selected because they are studying in an English-speaking environment at a joint Ukrainian-Chinese educational institution, Kyiv College. This institution is founded by KNUTD and the Qilu university at the Jinan City of Shandong Province.

The survey was conducted to identify the preferred learning styles of students. The instrument, known as Index of Learning Style (ILS) and developed by Richard M. Felder and Barbara A. Soloman (thereinafter Felder-Soloman's model) [26, 27] was used. Respondents were interviewed to respond to 44 questions and estimate available preferences in four complementary dimensions. The instrument categorises individuals in line with their preferences in perception – sensing (sen in short) or intuitive (int), input – visual (vis) or verbal (vrb), processing – active (act) or reflective (ref) and understanding of information – sequential (seq) or global (glo). The application of Felder-Soloman's model to students of different study areas was described in detail elsewhere [28, 29].

The existing learning environment allows optimising the use of e-resources according to individual preferences. Then the ease accessibility of e-resources for English language programs becomes an essential issue. Organising access to paper copies through the library significantly increases the cost of English-language learning. Therefore, having a full range of necessary resources in electronic forms is critically important. This paper analyses available statistics of students' accesses, normalised by the number of involved students, to e-resources related to the teaching of some special subjects at the Department of Professional Education in Technologies and Design. The dynamics of data retrievals in 2017-2019 are analysed for selected subjects and resources. Such analysis is necessary to test the preparedness of the existing learning environment to the introduction of English-language teaching and learning.

3 Results

3.1 Questionnaire results

The questions asked in the survey relate to the prerequisites for English-language learning, the dominant motivation of students and the student's preferences regarding the organisation of English-language learning, including financial aspects. The fundamental prerequisite for the organisation of English language training is the level of English proficiency among students. According to the Common European Framework of Reference (CEFR), learners' knowledge is divided into three groups (A, B, C), each of which is divided into two groups (Levels 1 and 2).

Students were asked to evaluate their knowledge according to this system. The questionnaire contained a detailed description of the requirements specific to each level of knowledge. Levels B and C, corresponding to an independent possession (Independent User) and free possession (Proficient User) were regarded as sufficient for mastering knowledge in English-language training. Therefore, the data for these levels were summarised, which simplified the overall picture.

Level A (Basic User) splits into half level A1 or survival level (Beginner and Elementary) and A2 (Pre-Intermediate level). It is usually insufficient for understanding lectures in a foreign language. However, the level A can be considered as a basis, which can be improved to the required minimum level B in the shortest time. The results of the survey are presented in Fig. 1 in the context of courses and faculties.

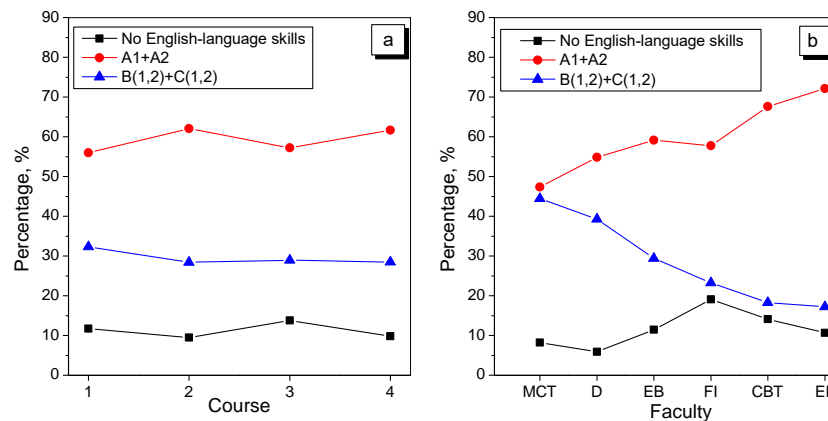


Fig. 1. Proficiency level in English language depending on course (a) and faculty (b)

Note that among university students, 89.6% studied English in the school. In comparison, all other foreign languages accounted for a total of about 10%.

Among those who studied English, about 10-13% said that their knowledge was at a zero level. This indicator remains stable for all courses (Fig. 1a). About 30% among the remaining students declare knowledge at level B or C; 60% (most) – at level A. Therefore, a third of students are well prepared for the perception of English-language

education. About 60% can reach this level after some preparation.

Unlike the distribution of courses, the distribution of knowledge between faculties is less uniform (Fig. 1b). The maximum values of untrained students are observed for FI (about 19%) and minimum for D (8%). In comparison, the value of untrained students varies within 10-13% in other faculties. On MCT and D, knowledge at the B + C level has 30-40% of students, and the number of students who do not have sufficient knowledge is about 6-8%. In contrast, only 20% are with the knowledge of B + C at the Faculties of FI, CBT, EL and EB. The number of students who do not know the language is maximum in comparison with other faculties. The decrease in knowledge at the B + C level from faculty to faculty is usually offset by an increase in the share of students with knowledge at level A (Fig. 1b).

Thus, there are potentially large numbers of students who have the required level of preparation for English language training. However, for such a transformation to be successful, it is necessary to understand how many students really want English language training. The results of the survey on this issue are shown in Fig. 2.

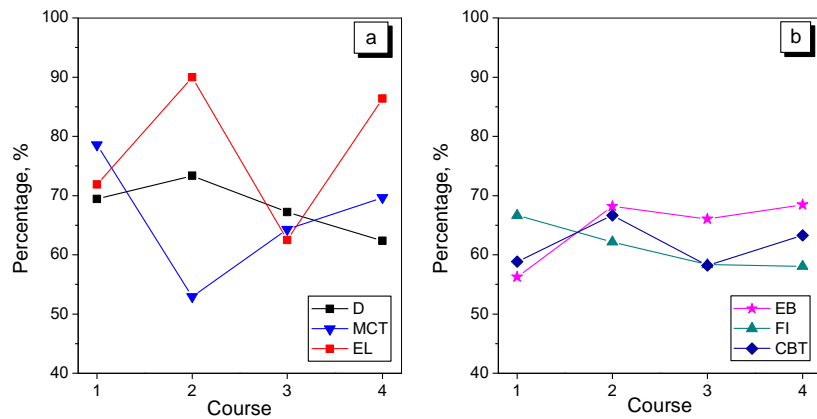


Fig. 2. The relative number of students who want to study English for students of 1-4 courses at different faculties: a – MCT, D and EL, b – EB, FI and CBT

The KNUTD average is almost 66%, while the results for different courses vary in a wide range of 55% and 90%. For most faculties (Fig. 2b), the research indicator remains relatively stable and slightly dependent on the course.

For two faculties, namely MCT and D (Fig. 2a), fluctuations from course to course are more significant. The MCT, EL and D rates, shown in Fig. 2a, are on average slightly higher (above 68%) than at other faculties illustrated in Fig. 2b (less than 64%).

At least two-thirds of the students surveyed are interested in English-language training. Four questions were formulated in the survey to identify the real motivation of the respondents. Two questions concerned the assessment of views on further employment, and two on possible ways of further education (Fig. 3).

Overall, according to the respondents, learning English is more necessary for further employment (Fig. 3a). Thus, in fact, 100% of students, who have shown

interest in English-language studies, are simultaneously considering for themselves employment abroad. At the same time, about 80% of respondents do not rule out intentions to start their businesses. Regarding further education (Fig. 3b), only 40-60% of those interested in learning English has the advantage of possible study abroad. However, among those who are considering admission to graduate school. 90-100% recognise the need for English language training.

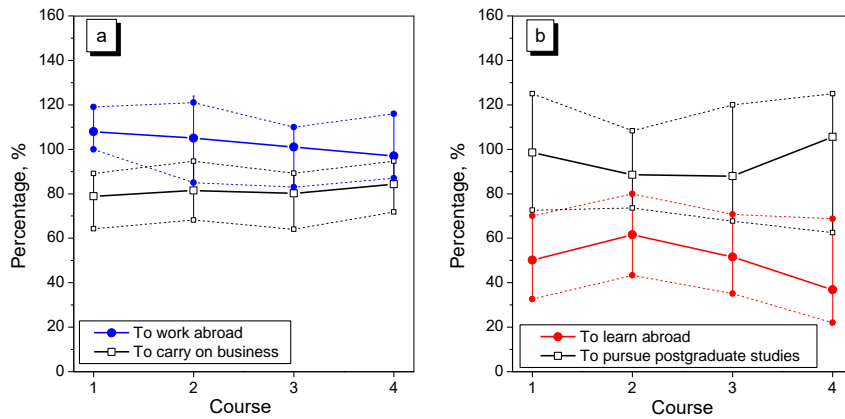


Fig. 3. The motivation for English-language learning: a – motives for employment, b – motives for further learning

An important aspect is the study of the forms of English-language teaching that most meet the expectations of the respondents. The survey suggested identifying the available preferences concerning four forms of training (Fig. 4).

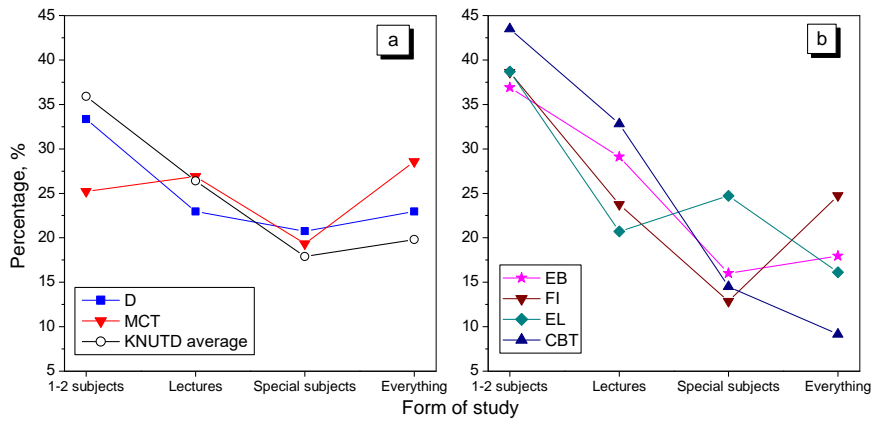


Fig. 4. Available preferences in learning forms

The most relaxed mode is to teach 1-2 subjects in English and continue to use Ukrainian in teaching other disciplines. An alternative model is to introduce English-

language teaching for 100% of the subjects. Two intermediate forms include teaching special subjects in English and fundamental subjects in Ukrainian or giving lectures in English and teaching practical classes in Ukrainian.

The most relaxed model for the gradual introduction of English-language teaching is somewhat prevalent over others for all faculties (Fig. 4). However, the difference in preferences over more fundamental models of teaching is small in those faculties (MCT and D) whose students declare a little better knowledge of languages (Fig. 4a). For example, MCT students did not actually find a preference for any learning models, each accounting for 20-28% of the total.

If students show a slightly lower level of language proficiency (four other faculties), up to 35-45% favour partial English-language teaching. For example, only 10-20% are supporting a full transition to English teaching (Fig. 4b).

Currently, students of Ukrainian universities study both for free on a paid basis. In the first case, education costs are covered from the country's budget (from now on referred to as the budget students). In the second case, there are concluded contract between a university and a student (contractual education). In conditions of limited public funds, an essential issue for the introduction of English-language education is the willingness of students to use the contracted form of education. The survey results are shown for all students (Fig. 5a) and separately for budgetary and contractor students (Fig. 5b).

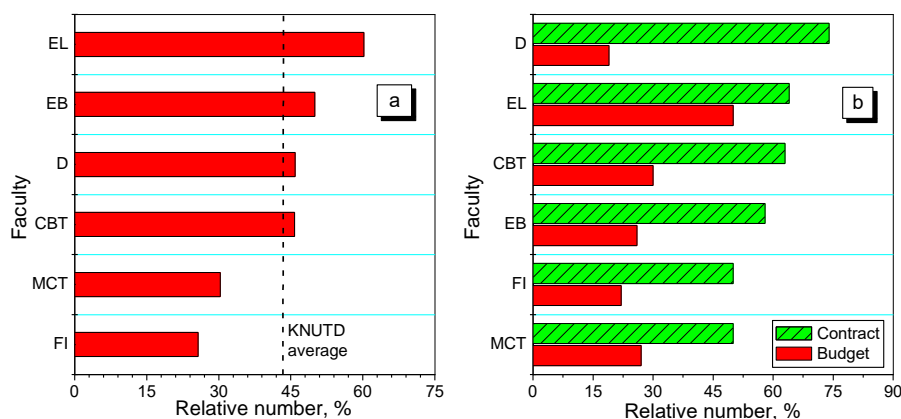


Fig. 5. Distribution of willingness to pay money for English-language learning by faculties (a) and by forms of education (b)

On average, about 43% of all English-speaking students are ready to introduce English-language training on a contractual basis (Fig. 5a). This indicator varies from 60% (Faculty of EL) to 25% (Faculty of FI) for different faculties.

It is not surprising that the number of students who approve of paid English-language studies is much higher among those who study on a contract basis (Fig. 5b). The difference between the contractual and budgetary students is almost four times for the Faculty of Design and is only 30% for Faculty of Entrepreneurship & Law. For other faculties, this difference is stably on a level of 2-2.5.

3.2 Preferred learning styles

Figure 6 illustrates some results of the study of learning preferences for students of different specialities at KNUTD. A good coincidence of learning preferences is observed between Ukrainian students studied pharmacy and chemistry at the KNUTD (Fig. 6a). Students are mainly characterised by active (71-73% of all students), sensing (82-83%), visual (78-81%) and sequential (64-71%) styles.

All these indicators are typical for students of the natural fields of studies [30]. It was also shown in previous works [30] that the learning profiles of undergraduate students remain practically unchanged during the studies in baccalaureate, demonstrating the stability of the educational preferences gained.

On the other hand, a significant difference exists between the profiles of Ukrainian design and technology students of the KNUTD and Chinese technology students of the Kyiv College at Jinan (Fig. 6b). The domination of visual style over verbal style (85% vs 15%) and moderate prevalence of active and sequential styles (65% vs 35%) compared to ref and glo styles, respectively, are typical for Ukrainian students.

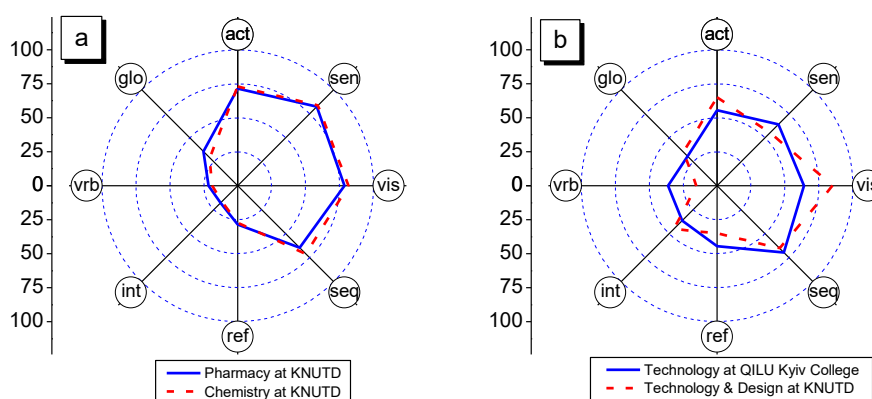


Fig. 6. Preferred learning styles of students of different fields of study

In contrast, Chinese students are significantly more verbal (36% verbal students compared to 64% visual) compared to Ukrainian students of similar specialities (15% verbal vs 85% visual). They are also a bit more reflective: 44% and 56% of Chinese students at Kyiv College are reflective and active, respectively (Fig. 6b). In comparison, the same results for Ukrainian students are 35% and 65% (Fig. 6a).

In dimensions seq-glo and sen-int, the measured difference between Chinese and Ukrainian students is minimal; it never exceeds 5%.

In general, students specialised in technology exhibit a more balanced profile of learning preferences compared to students of natural fields of study.

From a practical point of view, the identified difference in learning preferences must be taken into account. In particular, when developing educational materials and organising the English-language training for students of Ukraine and China. Such an adjustment can be made using the existing MEEP system. The flexibility and

sensitiveness of this system will be partly verified in the following paper section.

3.3 Access to e-resources within the existing learning environment

Another aspect that requires research in the context of English-language learning is the adaptability of the existing electronic environment to the changes that are needed. One such change is the need to provide students with English-language learning materials. Such a task cannot be solved within the traditional approach, which relies solely on printed matters but requires the involvement of several e-resources. It should also be remembered that the effectiveness of the use of e-resources depends on consistency with the preferred learning styles [25]. In turn, as already shown, learning styles of students of different fields of study backgrounds can vary widely.

Therefore, it is of interest to study the characteristics of existing e-resources, organise access to them within the existing MEEP system, and the popularity of various resources among students. The existing MEEP system allows one to study resource demand and the ease of access to it by examining the number of resource requests over several years of study.

As an example, the characteristics of e-resources used in the teaching of a few special subjects at the Department of Professional Education in Technologies and Design (Faculty of Fashion Industry) were investigated over the last three years.

The full and short names of the disciplines are as follows: imagology and the basics of engineering and pedagogical creativity; communicative processes in pedagogical activity; professional training methods; professional pedagogy; creative technologies of teaching.

The results of the study are shown in Fig. 7.

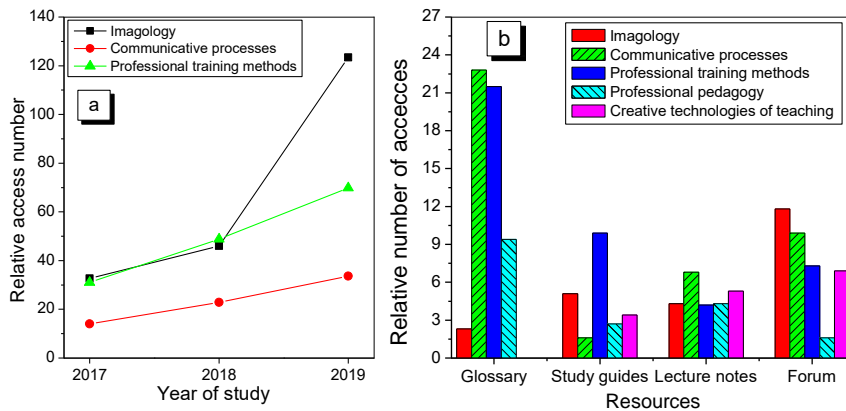


Fig. 7. The number accesses, normalised to the number of students, to available e-resources of the Department of Professional Education in Technologies and Design: a – average yearly accesses to all resources of the discipline; b – average yearly accesses to some individual resources of various disciplines

Figure 7a illustrates the dynamics of data retrievals for all resources available for each of the three randomly selected disciplines since their publishing in the MEEP system. Two findings are apparent. First, the average number of data retrievals is increasing, which indicates a growing demand for resources. Second, the figures for different disciplines are noticeably different. Among the reasons may be the varying resource numbers and quality, compliance with prevailing learning styles, the particularities of teaching discipline, etc. In any case, more research is necessary to answer the question definitively.

Figure 7b illustrates the frequency of accesses to individual resources averaged throughout 2017-2019. Some less popular resources, such as training programs, materials for practical and independent work, control issues, recommended literature lists, etc., are excluded from the analysis. Some resources have been merged. For example, lectures include lecture notes, e-books & presentations, and dedicated videos. The results obtained are also characterised by high data divergence. However, in general, they indicate the popularity and high demand for available resources.

4 Discussion

An analysis of the results obtained indicates the availability of a sufficient resource for those wishing to organise English-language training. Such a conclusion is based on the following identified facts.

1. 90% of students studied English at school.
2. Among them, 30% of students have a sufficient level of knowledge, such as levels B and C, according to CEFR.
3. Up to 60% more can relatively easily and quickly reach the required level. These students must improve their proficiency from level A to level B.
4. About two-thirds of those who study English are interested in introducing English-language instruction. Despite some variability of the results, in general, the indicators of KNTUD are quite homogeneous in faculties and courses.
5. The motivation for English-language training is primarily connected with the opinion that such training will contribute to career growth.
6. Language proficiency influences the priority model of learning. The faculties, where students have better knowledge on average, do not deny more radical models of English-language teaching. A more cautious attitude towards different models of learning prevails at faculties where knowledge is weaker than in others.
7. The fact that about 43% of the number of students consider English language teaching on a contract basis is significant. More loyal to this model were students of the contract form of study. Among them, the number of students who agree to pay tuition is 1.5-4 times higher than among budgetary students.

The understanding of learning preferences is a prerequisite for the efficient use of ICTs in education [25]. Therefore, the identified difference in learning preferences must be taken into account when developing educational materials. This statement is

illustrated by the example of teaching Ukrainian and Chinese students with different ratios of vis-to-verb styles (Fig. 6b).

Students with a distinct visual learning style better remember for what they see - pictures, diagrams, flowcharts, graphs, movies and visual demonstrations. Verbal students are more likely to receive information in the form of words - written and oral explanations. The optimal pedagogical approach to the organisation of training, as well as the optimal teaching methods, should be different for students with different preferences. Only those e-resources, which are qualified for the use in teaching students with preferred visual and verbal learning styles, are shown in Table 2.

Table 2. Integration of methods and e-resources for visual/verbal dimension

	Visual	Verbal
Characteristics of student style	Well perceived and better-memorised images: drawings, diagrams, charts, graphs, etc.	Well perceived language and text elements, more information is obtained from words - written and oral explanations
A pedagogical approach to the organisation of learning	Both types study better when the teaching material is presented both visually and verbally	
	Students better remember what they see	They quicker perceive spoken or audio information. It is better to remember what they read or hear
Learning best-suited methods	Visual, practical Problem-searching Modelling Experiment Games and simulations Independent work with training programs and simulators	Verbal, visual Problem-searching Lecture, Exercises Method of questions and answers Discussion panel Brainstorm Individual work with text Work in the group can be particularly useful: students achieve an understanding of the material, hearing the explanations of the groupmates and learn even more when they explain the material
E-resources qualified for use	Static and dynamic visualisations Quantum chemical simulation of spectra Modelling of experiments Virtual labs are best suited for learning Teaching programs Teaching database Tests ready for use	Static visualisation Quantum chemical simulation of spectra Lab complex with measuring sensors E-textbooks Chat, E-mail Teaching programs Search engines

Integrating aspects of styles, and selecting e-resources and teaching methods allow one to change the teaching methodology, focusing on the characteristics of students. The main stages of the developed approach are as follows:

- the development of a training and work program, and the establishment of objectives of the study of a discipline;

- investigation of the composition of a student group by Felder-Soloman's model;
- selection of teaching methods and essential electronic resources according.

The optimal methodology seeks to balance teaching and learning styles rather than to achieve absolute consistency between each lecturer's action and students' learning preferences. The discomfort should not be significant when students work according to a method that does not fit their learning styles. However, some discomfort is necessary for the formation of knowledge and qualifications of a future specialist. Entirely consistent with student's learning preferences, teaching methods do not create conditions for their progress.

The results show that the existing MEED system allows ones to operate effectively with e-resources and organise access of students to information regardless of the language of study. The fullness of e-resources in demand is a critical requirement in creating conditions for efficient English-language training.

5 Conclusions

A survey of 1,414 students of KNUTD showed the existing high demand for English-language education. 59% of all students surveyed or 66% of those who studied English in school expressed interest in English-language learning.

The demand for English-language teaching is supported by a reasonably high level of language proficiency. Of the 1,414 students, about 90% studied English at school. The survey showed that out of this amount, approximately 30% possess knowledge at level B or C, which is sufficient to accept training materials in English. About 59% show knowledge at level A, which requires some improvement but simultaneously can be considered as a basis for improvement which, if desired, can be amended quite quickly. Only 11% are feeble in English.

The motivation for English-language training is primarily connected with the opinion that such training will contribute to career growth. The second most important motivating factor is studying abroad or in graduate school.

The basis for organising English-language training should be considered the readiness of approximately 44% of students to participate in programs on a paid basis. This figure is lower among budgetary students and, depending on the faculty, is 1.3-4 times higher for students of contracted forms of education.

Among the proposed forms of training, the easiest one prevails over others, when training begins with teaching 1-2 disciplines in English. This form dominates in those faculties where students show a lower level of English. At the faculties, where the level of knowledge is high, there are no noticeable preferences among the forms of training. In essence, approximately the same percentage of students are ready for a complete transition to English, as well as for various forms of partial study.

The understanding of learning preferences is a prerequisite for the efficient use of ICTs in education. Therefore, the identified difference in learning preferences, illustrated by the example of teaching Ukrainian and Chinese students, must be taken into account when developing educational materials.

The readiness of the existing learning environment was tested by analysing the organisation of access to English-language teaching materials, assessing the demand for different electronic resources. The results show that the existing MEED system allows ones to operate effectively with e-resources and organise access of students to information regardless of the language of study. The fullness of e-resources in demand is a critical requirement in creating conditions for efficient English-language training.

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A Unification of the Study of Terminological Resource Management in the Automated Translation Systems as an Innovative Element of Technological Training of Translators

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Abstract. The article deals with the issues of improving the technological training of translators by introducing innovative elements within special courses or modules. A unification of the study of the same key operations of managing terminological resources in automated translation systems, which are used to support both simultaneous interpretation and translation, is proposed. The analysis of software products from the category of CAI (Computer-Assisted Interpreting) and CAT (Computer-assisted translation) for the revealing common characteristics in the aspect of working with terminological resources is made. An attempt has been made to optimize the technological training of translators for performing operations of search, selection, structuring, import, export of terminology, which is organized in the form of specialized terminological bases. The expediency of studying by future translators at least one of the software products related to CAI, one to cloud-based CAT, and one to desktop CAT is justified. The principles on which the process of optimizing the content and organizing the technological training of translators should be based are determined.

Keywords: Terminological Resources, Terminological Bases, CAT, CAI, Technological Training of Translators.

1 Introduction

1.1 The problem statement

With the rapid development of information technologies, they are widely introduced in all areas of professional activity, even in those where their use was not decisive for the effective achievement of high results. These technologies have already become an integral part of the translation technologies, but the area of simultaneous interpretation, until recently, had little in common with the achievements that can be drawn from them. However, the day-to-day work of an interpreter is becoming more diverse, requiring new ways to solve complex professional tasks. The usual functions of the translator are

changing, new horizons of the professional field of his activity are opening up, and combinations of various types of translation appear. In particular, the emergence of so-called trans-interpret, that is, translators who combine translation and interpretation, is already noted, as evidenced by the new designation of their activities, made up of two words (English: translator and interpreter) [1]. Objective circumstances prompt universities that train translators to reorient and modify their programs, strengthening the technological component.

The purpose of the article is to analyse the content of the technological training of translators and to improve it by unifying the study of basic operations with terminological resources when performing translation and simultaneous interpretation using automated translation systems.

To achieve this goal, theoretical and experimental research methods were used. The method of analysis and synthesis allowed us to determine the state of study of the research problem, to determine the main research area and the tasks to be performed. The comparison method was used to identify common aspects in the process of creating electronic terminological databases for CAT and CAI to implement their study into the technological training of translators. The use of the questionnaire method was necessary to obtain data from students on the effectiveness of parallel study of software products for CAT and CAI. We used the generalization method to determine the main results of the research and to provide recommendations for their use in the educational process of universities that provide translators training.

1.2 Literature review

Despite the changes in the practical activities of translators due to the life of society at the present development stage, including the appearance of a combination of translation and interpretation during professional tasks, research on the technological training of future translators focuses mainly on the study of the functioning of CAT tools as part of practice courses of translation techniques. In particular, considerable attention is paid to the terminology management, which, according to Bruno Ciola, is “an important area of translation environments” [2]. Advantages of terminology management in translation and localization projects are highlighted in the works of Miloš Matović [3]. Terminology using specialized tools in translation environment is considered by Marta Gómez Palou Allard [4]. The benefit of terminology in translation for businesses and economics is proved by Nataly Kelly and Donald A. DePalma [5], and Kara C. Warburton points out the need to overcome differences between terminological bases and electronic linguistic corpora [6].

The terminology accumulates in the terminology databases that store the terms with additional information (a brief description explaining the term, or examples of context that show how the word is used). As Bruno Ciola points out, working with terminology can be done in advance – for example, when preparing a translation task, or directly when translating or editing translated texts [2]. Stressing the need to study terminology management in the framework of university programs, María Fernández-Parra emphasizes the benefits of such knowledge for future translation activities and identifies issues for study. Namely storing in terminological databases and adding to them, depending on the level of complexity of CAT tools, different types of information

about terms, such as definitions, part of speech, usage, subject area, etc. In addition, according to the researcher, terminology bases in CAT tools are much more efficient than using spreadsheets such as MS Excel. They may also allow hierarchical organization of information. Analysing several CAT systems, Fernández-Parra sees the advantage of the SDL MultiTerm terminology databases over others, such as, for example, Déjà Vu, in that it allows including not only descriptions, but also multimedia information, such as graphics, video and sound files [7, p.393].

Undoubtedly, among the research on terminology management in the works of scientists, studies related to CAT tools prevail. The problem of lack of relevant scientific achievements is ascertained by Hernani Costa, Gloria Corpas Pastor and Isabel Durán Muñoz, noting that, unlike many computer translation tools, there is still only a limited range of interpretation tools available [8]. According to scientists, interpreters are faced with different settings and specialized domains, where computer-supported tools may be useful. Specialized computer and mobile software could be used to assist translators in compiling, storing, managing and searching terms in glossaries [9; 19]. Recently, there have been studies by other foreign scholars on issues related to the terminology management in CAI tools. They are not numerous, but they outline promising directions and trends that should already be taken into account in the translators' training process. In particular, while conducting research on the introduction of CAI learning into a university program, Bianca Prandi argues that there are three undeniable truths about CAI tools: they can provide many terminological support benefits, they should be used strategically, and most translators know very little about them [10]. At the same time, from the point of view of C. Fantinuoli, one of the developers of the InterpretBank desktop software designed for professional translators, without the latest technologies, including terminology, there can be no effective interpretation. Speaking about changes in interpretation technologies, he noted that they are happening quickly and independently of us. According to Claudio Fantinuoli, it is a "technological turn in interpretation" [11]. As new software products began to appear on the translation services market specifically for the technological support of interpretation, attempts were made to analyse them. In particular, Hernani Costa, Gloria Corpas Pastor and Isabel Durán Muñoz [8] present a comparative evaluation of terminology management tools for interpreters by their users.

2 Result and discussion

When performing simultaneous interpretation, one of the types of traditional information resources of a translator is a terminological resource in the form of dictionaries or glossaries. However, despite the rather rapid development of information technologies and software that allows for structuring terminological data, it almost did not affect the way and approaches to their use in the process of interpretation. This is primarily due to the interpreters' lack of confidence in the capabilities of the terminology systems, due to their imperfections in entering queries, obtaining relevant results, clarity of presentation and choosing the right terms. However, recent developments in the field of simultaneous interpretation support systems indicate a new level of software in this area. In particular, a second generation

of these programs has emerged today, which is positioned as Computer-Assisted Interpreting (CAI). They are fundamentally different from previous generation programs that most of the interpreters are familiar with, but they unfortunately have not become their reliable assistants. Unlike conventional terminology management, modern systems provide three key functions [12]:

1. Preparation for interpretation. In this case, it is supposed to work with a database with auxiliary material, the possibility of automatic synthesis of documents, the function of extracting terminology and storing terms.
2. Support during the immediate execution of translation tasks covers both manual search of terms and automated search based on voice recognition.
3. Support for the processing of information after completion of the direct translation process – replenishment of terminological resources, assessment of the quality of the translation and reporting.

However, despite the presence of these functions in the CAI, their popularity among simultaneous interpreters remains low. A prerequisite for the widespread introduction of such systems in simultaneous interpretation processes should be a number of strategic steps, both from the side of their developers and from educational institutions that train translators for this type of translation.

In particular, the developers of CAI should offer such a level of these software products that would allow, first, due to the functionality and features of the interface, to achieve the maximum effectiveness of terminological support in the implementation of simultaneous interpretation. High efficiency must also be ensured at the preparatory stage, which involves searching for industry texts, selecting terminology, preparing glossaries, mastering terminology, and more. An equally important step on the part of the developers of CAI is building partnerships with educational institutions to improve the skills of new translators. Instruments are more likely to become more familiar if new practitioners are introduced to these opportunities at school and are expected to work in their working environment [12].

In their turn, educational institutions should also be aware of the importance of training future translators in terms of mastering modern tools. This applies not only to the study of computer-assisted translation (CAT) [13], which has already been widely introduced into the content of the training of translators by leading universities of the world [13], but also to CAI. Of course, in this aspect, traditional questions arise: what software products to study, what should be their optimal amount, how much training time should be allocated for their development, etc. However, despite this, the activities of universities should undoubtedly be aimed at introducing modules, theoretical and practical courses, or at least issues related to the study of CAI. This work has already been started by many universities that have introduced purely theoretical courses as well as theoretical courses in combination with practical courses, workshops, etc. into the structure of translators' training. At the same time, not only the forms of training but also the software products based on which the CAI study is carried out are diverse. In particular, universities do not prefer any one software product, but study different, and in some cases from 3 to 6 at the same time [14]. The list of CAI products currently being studied at universities includes InterpretBank, Intragloss, Interplex, LookUp,

Interpreters' Help and more. In our opinion, an integral part of the content of the study of these systems should be the formation of terminological resources organization, which will provide terminological support for interpretation. The effectiveness of mastering terminology resources in these systems will largely depend on the use of prior knowledge. Extremely useful may also be the experience of preparing terminological resources for their use in CAT during translation. Therefore, at the initial stage of the study, we focused our efforts on identifying similar operations for the organization and management of terminology when working with CAT and CAI.

First, we tried to optimize the technological training of translators for the search, selection, structuring, import, and export of terminology, which is organized in the form of specialized terminology bases. This is due to the coincidence of a large number of the same types of implementation of these operations, some of which can be done using office suite programs, some through the Internet, and the vast majority using the corresponding features available in automated translation support systems, including in CAT and CAI. For example, it is advisable to structure the terminology data by means of a word processor and a table processor, and then import it into the terminology database. The process of obtaining industry-specific terminology databases can be accelerated by leveraging available Internet resources and relevant search engine tools. In this case, preparatory work can be directed both to the search of ready bases and to the selection of texts on the issue of future translations, which can become donors for the extraction of terminology. However, most of the operations can be performed using functions available in automated systems aimed at extracting, structuring, importing, exporting terminology, and more. In order to improve the technological training of translators and to unify approaches to the study of basic terminological resources operations in the implementation of translation and simultaneous interpretation with the use of CAT and CAI, we have selected the following software products for comparison: InterpretBank (CAI), MemSource (cloud CAT), SDL Trados (desktop CAT). Unlike the well-known and widespread CAT SDL Trados and MemSource, CAI InterpretBank has relatively recently made its way into the software market, but is gaining popularity. This is evidenced by the sufficiently broad list of universities that use this software in the translators' training system. InterpretBank is software developed as part of a research project at the University of Mainz / Gernersheim. The overall goal of the tool is to create a translator workstation, which allows optimizing the workflow before, during and after the event where the simultaneous interpreter performs simultaneous interpretation [11].

When preparing glossaries to work with both CAT and CAI, the experience gained in the initial stages of translator training in using information technologies to translate is important. First, these steps involved the structuring of terminological data using office suite programs [15; 17]. In particular, the ability to use MS Word and MS Excel for these purposes will enable future translators to adapt easily to the creation and completion of terminology databases. This is possible, first, because CAT and CAI allow the import of terminological data structured in simple constructions. Such constructions may include only tabular terminological entries in two languages, where the correspondences are placed within a single line. It is also possible to import structures with more complex terminological record, they may contain a certain number

of synonyms in both languages, definitions, information about sources of information, and other additional information. However, in this case, it is necessary to take into account the features of each program, since such functions may not be implemented in each of them.

It is important to note that XLS (XLSX) format deserves special attention when structuring terminology material, as it is a common format for importing data into most CAI and CAT tools. In particular, this format allows importing terminology records to terminology databases in cloud-based CAT such as XTM Cloud, Wordfast Anywhere, MemSource, MateCat, etc. [16; 18]. General principles for structuring terminology data using MS Excel for later import can also be used when working with desktop CAT, in particular SDL Trados. However, this is only possible initially; the next steps require converting XLS terminology data to XML format. In general, the generated skills of structuring terminological records using MS Excel are unified to perform preparatory operations for interpretation using CAI and translation using CAT. The only difference is the use of different coding systems to mark languages according to standards.

The preparation of terminological data for further import into terminological databases is an important element of the work when translating using CAT and CAI. However, the vast majority of terminology actions when working with these systems are done directly in the terminology editors. When using InterpretBank as a CAI, this system has in its structure a separate module designed to create and manage specialized terminology bases. Using this module allows to create a separate glossary or sub-glossary system in preparation for a specific simultaneous interpretation task. The filling of these terminological databases can be efficiently done manually, as the available functional tools and a clear interface facilitate this. Performing such operations with terminological material as entering a new term, moving it to the list, editing it, writing additional information, deleting are basic and sufficient to effectively manage the terminology within a separate database.

Forming the skills of future translators to perform these operations may be unified to work with CAT editors. This is primarily due to similar approaches of software developers to the structure of working icons, the organization of the interface, the logic of action, etc. These aspects should be the basis for the unification of approaches and the students' attention should be focused on this in their learning process. An example of the formation of a terminological base for interpretation support using InterpretBank as a CAI is shown in Figure 1.

The base thus formed is the basis for the use of other modules that are in the structure of InterpretBank, namely the terminology memorization module and the terminology access module during simultaneous interpretation.

The structure of records management in the MemSource CAT terminology editor is shown in Figure 2.

A parallel study of working with terminology database editors of various software products from the CAI and CAT categories will allow, based on a comparison of common features and differences, to form not only a stable ability of future translators to form terminology databases, but also the ability to adapt to performing these tasks in various software products. It can also be an additional element of motivation in the process of studying these technologies.

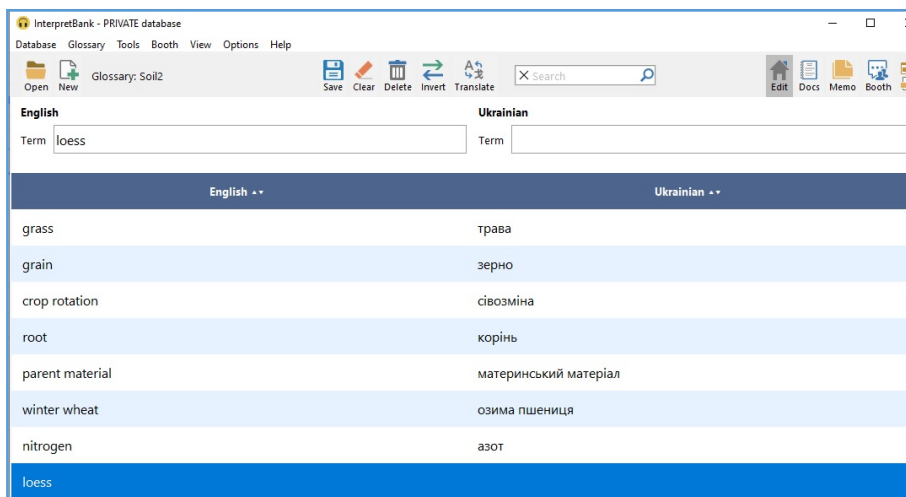


Fig. 1. Structure of the InterpretBank terminology database editor.

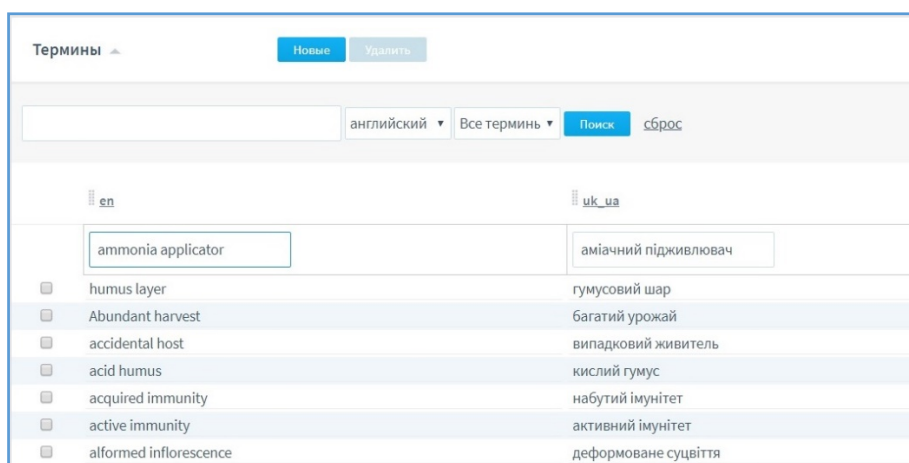


Fig. 2. The structure of records management in the editors of the terminology databases of the MemSource CAT.

One of the important operations in the structure of a set of measures for the creation and filling of terminological bases for both CAT and CAI is the extraction of terms from texts that are source for translation. This is a very effective way to formulate a terminological framework to support translation (or simultaneous interpretation) with such a set of terms as are guaranteed to be available in the text of the report or in the text for translation. There are a number of specialized programs related to the extractor group for the extraction of terms in the application of CAT. One of the most common programs in this group is SDL MultiTerm Extract. In our opinion, developing skills to work with this program is an integral part of the content of the study of CAT. The

advantages of using extractor programs as a whole, and SDL MultiTerm Extract in particular, are the ability to analyze texts to detect terms in automatic mode. The translator only has to choose from the proposed list those terms that he thinks should be added to the terminology base. The system helps to make the right decision by scoring a certain number of points against each entry. Entries with high scores are more likely to be terms. Although this technology requires separate software and the ability to use it, its overall performance is much higher than when manually searched and typed terms into the database.

In the process of mastering the technology of extracting terms from texts, understanding the file formats in which the source texts can be represented is important. In the case of SDL MultiTerm Extract, the terms can be extracted from texts in different languages, which are saved in text formats, including TXT, RTF, DOC, DOCX, ODT, and in other formats XLSX, PPTX, ODS and more. Understanding the nature of the formats used in terminological data is another aspect of the unification of translators' training, since the vast majority of programs use common formats.

Figure 3 shows the structure of terms extracted from the text by SDL MultiTerm Extract at the stage of their selection by translator.

Score	Domain	
99	<None>	<input checked="" type="checkbox"/> soil sample
99	<None>	<input checked="" type="checkbox"/> permanent wilting point
99	<None>	<input type="checkbox"/> particle size analysis
99	<None>	<input checked="" type="checkbox"/> organic matter
99	<None>	<input checked="" type="checkbox"/> field capacity
99	<None>	<input checked="" type="checkbox"/> clay
99	<None>	<input type="checkbox"/> calculated by the formula
99	<None>	<input checked="" type="checkbox"/> Brown Forest Soil
98	<None>	<input type="checkbox"/> Determination of Exchangeable
96	<None>	<input type="checkbox"/> Parent Material
93	<None>	<input type="checkbox"/> sieve

Fig. 3. Structure of the recording of terms extracted from the text by SDL MultiTerm Extract.

In the case of using InterpretBank as a CAI, the functionality of this system also allows for the automatic analysis of texts for the presence of terms. From the texts that will be used in the report in a foreign language, the terms are extracted according to certain algorithms, and their list is formed in order of frequency of their appearance in the text. Thus, the translator is given the opportunity not only to select from the list the necessary terms, but also to receive their translation based on connected electronic dictionaries and systems of machine translation. The process of such an operation is clear, and the program interface allows easily and quickly processing the necessary texts and forming terminological bases at the stage of preparation for simultaneous interpretation (Fig. 4).

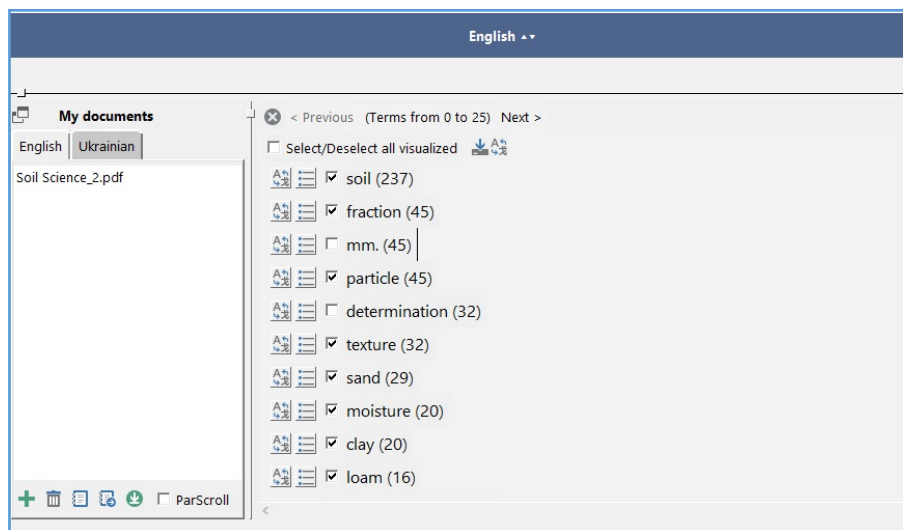


Fig. 4. Structure of organization of terms extracted from the text by means of the corresponding InterpretBank module.

As with SDL MultiTerm Extract, InterpretBank allows to extract terminology from texts written in different languages and presented in different text and other formats. Particularly valuable is the ability to extract terms from text in PDF format.

In view of the above, the technological training of translators in the terminological resources management, which can be used to support simultaneous interpretation and translation using CAI and CAT, should be optimized by unifying approaches to the study of key operations. Such operations, first, should include the selection, structuring, streamlining of domain terminology, and its import to terminology bases and export from them (see Table 1).

In our opinion, the process of optimizing the content and organization of technological training of translators should be based on the following principles:

- to study the systems of automatic translation used in both translation and simultaneous interpretation, the content of translators' training must be accompanied by specific courses or modules that provide both theoretical and practical components;
- in the structure of special courses it is expedient to study at least one of the software products related to CAI, one to cloud CAT, one more to desktop CAT;
- to take into account in the process of practical implementation of training of translators for the terminological resources management in the systems of automated translation, the expediency of simultaneous demonstration of the implementation of the same operations in the CAI and the CAT in order to form unified skills for their execution, taking into account the possible use of different programs;
- to emphasize on the initial stages of studying translators of office suite programs, in particular MS Excel, on developing the ability to structure terminological data in XLSX format, taking into account the peculiarities of using language codes and

- placing them in a table of terms, synonyms, additional information, etc., in accordance with their further use in the CAI and CAT;
- it is advisable to pay particular attention to the possibility of using in the process of preparation of electronic terminology bases for use in the CAT and in the CAI of the open terminological resources presented on the Internet, in particular, the EU IATE terminological database (Interactive Terminology for Europe);
 - practical tasks for mastering the operations of extracting terms from documents should be developed taking into account the need to use different formats for this purpose, in particular DOCX, XLSX, PPTX;
 - to draw students’ attention to the fact that it is expedient to select terminological material in terminological bases for AIS and CAT by domain specificity, structuring them, if necessary, according to a specific thematic hierarchy;
 - acquaint students with the policy of licensing software by developers, as they have in common a distinction between freelance programs and corporate programs, as well as some additional benefits (for example, one license for two devices, which allows the translator to use their terminology base as with desktop PC, and from a mobile device).

Table 1. Aspects of the unification of operations for terminology resource management.

Technological operation	Software product		
	SDL Trados	MemSource	InterpretBank
Import of structured terminology entries to xlsx terminology database	+ (with intermediate conversion)	+	+
Import of terms to tbx terminology database	+ (with intermediate conversion)	+	+
Export of terms from a xlsx terminology database	–	+	+
Export of terms from rtf terminology database	+	–	+
Exporting of terms from the tbx terminology database	+	+	+
Extract of terms from docx, xlsx, pptx texts	+	–	+
Creation of new terminological bases by means of built-in editors	+	+	+
Manually adding terms to new and existing terminology databases	+	+	+
Managing the terminology of the built-in editors (editing terms, extracting, moving)	+	+	+
Recording additional information on terms in descriptive fields	+	+	+
Recording and saving synonyms for terms	+	+	–
Finding terms in the database using the built-in editors	+	+	+

At the initial stage of development and introduction to the content of training of translators of this special course, its purpose was to develop knowledge and skills of working with desktop CAT on the example of SDL Trados, and later on cloud-based CAT on the example of MemSource. The next step in improving the technological training of translators was to introduce into their curriculum a special course in studying CAI using the example of InterpretBank. At this stage, an innovative change in the study of the special course was the beginning of the practice of parallel study of the same operations in different programs and systems, in particular, work with terminological resources and the creation of terminological bases.

To determine the effectiveness of this method of technological training of future translators for the use of automated translation systems, we conducted a survey of students who completed the course “Information Technologies in Translation Projects” with these innovations. In total, 33 students participated in the survey. The questions of the questionnaire provided several options for the answer, which were aimed at differentiating students’ understanding and attitude towards aspects of studying the special course. The contents and the results of the questionnaire are shown in Table 2.

The analysis of the questionnaires of the students showed, first of all, their positive perception of the introduction in the special course “Information Technologies in Translation Projects” of parallel study of CAT and CAI, as 60.6% of them rated this innovation unequivocally positive, and 24.2% answered “Rather yes, than no”. According to the majority of students (69.7% + 6.1%, that is, the total amount was 75.8%), studying terminology in software products related to CAT and CAI, contributed to the understanding of the general principles of the technology of creating terminological bases, and was one of our main goals.

More varied were the answers to the questions about the perception of the unification of the study of basic terminology operations in software products in the CAT and CAI categories as a technological advantage. Here we received positive answers from 78.7% of the respondents, but at the same time 6.1% expressed their doubts by choosing the answer “Rather no, than yes”. In addition, 9.1% do not consider the proposed innovation an advantage in technological training, and another 6.1% under “Other” said that unifying the study of basic terminology operations in several software products may be superfluous, and they will have to work with only one software. In view of the received answers, we see the need in the future to acquaint future translators in more detail with the changing situation in the translation services market. It is marked, on the one hand, by the rapid development of information technologies and the constant appearance of new software products, and, on the other hand, by the requirements of customers to use the specified software.

Equally ambiguous were the students’ answers to questions about their opinion on whether the knowledge of various software products facilitated the creation of electronic terminology databases for working with them. If 57.6% of students answered this question in the affirmative, and 15.1% said yes, then 9.1% tend to evaluate negatively the likelihood of facilitating the use of automated translation systems by gaining knowledge of various software products related to CAT and CAI. 12.1% unequivocally believe that this knowledge will not facilitate their terminological work with the use of the CAT and CAI software.

Table 2. Results of the questionnaire of students on revealing the effectiveness of innovative methods of technological training of translators.

Question	Answer options, %				
	Yes	Rather yes	Rather no	No	Other
Do you find it useful to study CAT and CAI in parallel?	60.6	24.2	9.1	6.1	0.0
Has the study of working with terminology in software products related to CAT and CAI contributed to the understanding of the general principles of the technology for creating terminology databases?	69.7	6.1	18.2	3.0	3.0
Do you consider the unification of the study of basic terminology operations in the CAT and CAI software products as an advantage in the technological training of translators?	63.6	15.1	6.1	9.1	6.1
Are you ready to make additional efforts to learn several CAT and CAI software products in parallel to help manage terminology more effectively?	54.6	3.0	24.2	15.2	3.0
Do you find it easy to know the various software products related to CAT and CAI to create electronic terminology databases for the work with them?	57.6	15.1	9.1	12.1	6.1
Did detailed knowledge of the features of one of the automated translation systems allow you to master the work with terminology in another software product quickly?	72.7	6.1	12.1	9.1	0.0
Did the knowledge of one of the automated translation systems complicate the study of another software product in terms of working with terminology?	9.1	12.1	24.2	51.6	3.0
Do you think that after studying the ways of creating terminological bases in the offered programs in the CAT and CAI category, you will be able to work with other similar programs in this aspect?	45.5	15.1	18.2	15.1	6.1
Has the CAT and CAI parallel study technique helped you overcome your fear of the latest technology?	75.8	6.1	12.1	3.0	3.0
In your opinion, does the parallel study of CAT and CAI offer greater opportunities for future employment?	72.7	15.2	3.0	3.0	6.1

From 6.1% of students, we received “Other” answers, which generally came down to the fact that expanding the range of software products offered to study, on the contrary, slightly disoriented them and made it difficult to perceive the features of certain terminology operations. However, only 9.1% of students answered “Yes” to the question of whether knowledge of one of the automated translation systems made it difficult for them to study another software product in terms of terminology. This means that the vast majority of students have been able to acquire the course material that has supplemented the special program without too much difficulty.

The large number of “Yes” answers (72.7%) to the question about the possibility of accelerating the study of terminology in another software product due to the detailed knowledge of the features of one of the systems of automated translation testify to the unconditional expediency of the innovative modification of the technological training of translators offered by us.

Another positive achievement of the introduction of the CAT and CAI parallel study method was that it helped students overcome their fear of the latest technologies. The number of students mentioned this: 75.8% – Yes, 6.1% – Rather yes, than no. In our view, overcoming psychological barriers is an important prerequisite for successful acquisition of knowledge and ability to work with modern translation tools, but unfortunately, teachers do not always pay attention to this.

However, it is worth noting that only 54.6% of students expressed their absolute willingness to make additional efforts to master concurrently several CAT and CAI software for better terminology management, which can be explained partly by their overload in the educational process and partly by a certain inertia in the perception of the new.

In general, an overwhelmingly large number of students – 87.9% (72.7% – Yes, 15.2% – Rather yes, than no) think that the innovation we offer is positive. The parallel study of CAT and CAI provides them with greater opportunities for future employment.

The unification of approaches to the technological training of future translators made it possible to improve significantly it and to form in them a comprehensive understanding of the essence of the use of automated translation systems. It means, in particular, the basic principles and approaches that underlie the structuring of terminological material, its extraction from texts, import to the database, export from the database, etc. A systematic understanding of these processes, which in many respects are common not only to the same programs from different developers, but also common to various CAT and CAI programs, will allow the translator to overcome the fear of using such systems in a professional activity, or to use the software product with which he had no previous experience.

3 Conclusions

The conducted research has made it possible to conclude that the technological training of translators at universities should be improved constantly in view of new technologies, software products and technological developments on the translation services market. They also lead to changes in approaches to the organization and

implementation of translation and interpretation, which as of today are not reflected sufficiently in translators' training curricula. The introduction of innovative elements in the technological training of translators is expected to have a number of positive impacts, in particular:

- will help to increase their competitiveness in future employment;
- expand the translator's ability to be involved in various areas of translation, both traditional and new, emerging at their intersection;
- accelerate adaptation to changes in professional activity that will certainly continue to occur in the translation services market;
- provide the translator with the ability to respond more flexibly to the requirements and wishes of customers regarding the use of certain software products during translation;
- will allow the translator to reduce the cost of retraining in the future if the need arises.

One of the innovative elements in the technological training of translators may be the method of unifying the study of terminological resource management in automated translation systems, which in particular provides for:

- introduction to the training of translators of the study of the systems of automated translation, which are used in interpretation and translation in the form of special courses / modules with theoretical and practical components;
- structuring of special courses taking into account the study of at least one software product in the following categories: CAI, cloud CAT, desktop CAT;
- parallel study of the same types of operations in the CAI and the CAT in order to form unified skills in their execution;
- development of practical tasks for mastering the operations of extracting terms from documents, taking into account the use of different formats for this purpose.

The first results of the introduction of such a method in the process of training of translators have already proved its effectiveness.

Further scientific research may be directed to a more detailed study of the effectiveness of introducing innovations in the technological training of translators, developing a methodology for learning modern translator tools, improving the offer of learning software products within certain courses.

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Methods of Designing Digital Learning Technologies for Developing Primary School Pre-Service Teachers' 21st Century Skills

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Abstract. The survey looks into the issue of designing digital learning technologies for training primary school pre-service teachers. The paper discloses the authors' conception of designing digital learning technologies for training primary school pre-service teachers, based on the digital humanistic pedagogy, the multiple intelligence theory, and the theory of open education. The authors present the model of designing digital learning technologies for training primary school pre-service teachers and diagnostic tools, which includes the criteria and indicators of the development of skills to use digital technologies for fostering students' skills. The effectiveness of the authors' methods which have interdisciplinary character and can be implemented into the study of a number of courses, is proved while conducting learning and research projects in formal and informal education.

Keywords: Digital Competence, Primary School Pre-Service Teachers, Multiple Intelligence Theory, Digital Humanistic Pedagogy, Theory of Open Education, Project Learning.

1 Introduction

The modern world is continuously changing and characterized by everyday upgrading of information. To be knowledgeable about the current affairs and trends, teachers should follow innovations both in their pedagogical activities and in various spheres of social life. The reformation of education directs teachers to the necessity to constant professional self-improvement that is caused by the need of meeting the requirements of the dynamic environment. The modern trends of developing social, cultural, and information aspects of pre-service teachers' training are of priority concern of the government that is reflected in the legal and regulatory documents, which define the priorities in education policy of Ukraine: "Strategy of Information Society Development in Ukraine" [1], the Law of Ukraine "On Higher Education" [2], Project

“Digital Agenda of Ukraine – 2020” [3], the Concept of the Development of the Digital Economy and Society of Ukraine for 2018–2020” [4], the Law of Ukraine “On National Program of Informatization” [5] etc.

So one of the priority directions of professional development of pre-service teachers is to enhance their digital competence. Digital competence includes the skills to use different tools (computers, software, local and global networks) and skills to effectively implement them into the pedagogical activities [6]. The high level of the development of primary school teachers’ digital competence becomes a key for the effective use of digital technologies in educational practices, as well one of the most important indicators of success of their activities and at the same time it is one of the conditions for further improvement of the level of teachers’ professional competence.

In 2006, the European Commission issued the research “Digital Competence in Practice: An Analysis of Frameworks”, which discloses that digital competence is an ability to confidently, critically and creatively use information and communication technologies for achieving the aims in the sphere of professional activities, education, leisure-time activities, and participation in social life [7].

As UNO document “Education Research and Prospects of Future Learning: What kind of pedagogies for the 21st century?” (2015) reveals, the framework of educators’ competences in international learning environment combines learning and innovative skills, so-called “4C”: cognitive, creative, collaborative, and communicative skills [8].

The scientists of the united research center of the European Commission have developed the European system of digital competence on the base of consultations and active collaboration with a great number of stakeholders and law-makers of such spheres as industry, education, professional training, and social partnership. Christine Redecker and Yves Punie have developed the framework of digital competence for educators (DigCompEdu). European system of educators’ digital competence describes the necessary tools for improving the level of teachers’ competence development in the sphere of digital technologies. The system of DigCompEdu is developed for implementing the joint approach to defining the main spheres of educators’ digital competence in European Union countries [9].

In the concept “New Ukrainian School: Conceptual Principles of Secondary School Reformation” (2016) it is stated that information and digital competence is one of the key competences for life [10].

The issue of pre-service teachers’ awareness of implementing digital technologies for intellectual, communicative, and creative development is methodologically significant. One of the relevant ways of developing pre-service teachers’ skills is using modern digital technologies and implementing project learning forms.

The implementation of project learning forms aims at the cognitive activities and creative self-realization of students that ensure the development of intellectual abilities, spiritual qualities, creative skills and, what is equally important, communicative and collaborative skills, as it is implemented by rationally combining theoretical knowledge and their practical use.

The analysis of domestic scientific sources provides the ground to assert that the theory and practice of education has accumulated a significant experience of upgrading the specialists’ professional training. However, the issue of designing digital

technologies for pre-service teachers' training that may become the basis for improving and developing the 21st century skills, as well their pedagogical skills, needs further studying.

In previous century, the dissemination of the multiple intelligence theory by Howard Gardner started the revolution of the understanding and development of cognitive processes in education and became a certain catalyst, which encouraged educators to rethink the learning practices. The approaches to integrating the multiple intelligence theory with digital technology in learning process is presented only in foreign scientific space. Domestic scientists have never studied the issue of designing digital learning technologies on the basis of using the multiple intelligence theory in primary school pre-service teachers' training.

The purpose of the paper is to substantiate the authors' conception, model and methods of designing digital learning technologies in primary school pre-service teachers' training and to experimentally prove its effectiveness.

The subject of the study includes theoretical and methodological foundations of designing digital learning technologies in primary school pre-service teachers' training.

The target problems of the research are:

- to substantiate the concept of designing digital learning technologies in primary school pre-service teachers' training.
- to develop the model of the system of designing digital learning technologies in primary school pre-service teachers' training.
- to define the criteria and indicators of the development of digital competence as an ability to design digital learning technologies for developing primary school pre-service teachers' key skills.
- to develop and experimentally check the methods of designing digital learning technologies in primary school pre-service teachers' training.

2 Research methods

To achieve the purpose and to solve the target problems of the study, general scientific methods are used which complement and provide the reliability and the validity of the obtained results when they are implemented in a complex way.

The theoretical methods include: analysis, synthesis, and generalization of scientific, learning and methodological sources for defining the state of investigation of the studied issue in foreign and domestic educational space and the essence of main categories of the study, conceptual foundations of the multiple intelligence theory; *netnography* for analysing the papers and blogs which contain the description of foreign experience to implement the multiple intelligence theory in educational practices; *modeling* for studying the features and relationships between the structural components of the process of designing digital learning technologies in primary school pre-service teachers' training; *designing* for developing a model and methods of implementing digital learning technologies in primary school pre-service teachers' training.

The empirical methods include: observation, survey, expert assessment, pedagogical experiment for testing the study hypothesis; *methods of mathematical*

statistics for quantitative and qualitative analysis and testing the validity of the experiment results.

As the research has a theoretical and empirical nature, its effectiveness was tested while conducting the pedagogical experiment (2013–2019), which included some stages:

1. The **preparatory stage** of the experiment (2013–2014) involved the implementation of the following steps:

- studying the theoretical foundations of designing digital learning technologies in primary school pre-service teachers' training;
- studying the foreign experience of implementing the multiple intelligence theory in the educational process;
- substantiating the conceptual research principles;
- substantiating the model of designing digital learning technologies in the primary school pre-service teachers' training;
- developing the methods of designing the digital learning technologies for enhancing students' digital competence for ensuring the improvement of their cognitive, creative, communicative, and collaborative skills;
- defining the criteria and indicators of the development of pre-service teachers' digital competence that is determined as students' ability to use digital technologies for developing cognitive, creative, communicative, and collaborative skills.

The authors' conception of designing digital learning technologies in primary school pre-service teachers' training is based on the foundations of digital humanistic pedagogy (Valerii Yu. Bykov, Mariya P. Leshchenko [11]), the multiple intelligence theory (Howard Gardner [12], Thomas Armstrong [13], Walter L. Mckenzie, Jr. [14]), the open education theory (Valerii Yu. Bykov) and the theory of teaching mastery (Ivan A. Ziaziun [15]).

The key idea is that the development of human abilities and their ways of perceiving and learning the information world is considered in accordance with Gardner's multiple intelligence theory. The development of cognitive, creative, communicative, and collaborative skills, which are the 21st century skills, is claimed to be designed taking into consideration the types of intelligence (logical-mathematical, verbal-linguistic, bodily-kinesthetic, visual-spatial, musical-rhythmic, intrapersonal, interpersonal, and naturalistic) and realized by using digital learning technologies that create the conditions for their development.

Designing digital learning technologies in primary school pre-service teachers' training focuses on fostering their digital competence, based on humanistic-technological and intellectual-multiple approaches.

The humanistic-technological approach justifies the creation of the blended learning environment, which combines both bio and techno components to develop and apply students' skills through acquiring competence by using technological tools, designing and implementing digital learning technologies, and solving various technological problems.

The intellectual-multiple approach to designing digital learning technologies for enhancing students' cognitive, creative, communicative, and collaborative skills ensures the improvement of their digital competence and contributes to searching and forming the pre-service teachers' professional identity by making the reasonable choice of digital technologies, forms, and methods, depending on the dominant types of their intelligence and individual profile of each student for solving educational problems.

The developed model of designing digital learning technologies in primary school pre-service teachers' training includes target, content-technological, operational-technological and resulting components.

The *target* component of the model characterizes the focus of the students' learning system on designing digital learning technologies to develop their key competences of the digital society. The target component is presented in the purpose specified in the defined targets.

The purpose is teaching to design digital learning technologies by improving the digital competence for developing cognitive, creative, communicative, and collaborative skills of future Bachelors of primary education.

Specifying the purpose of the development process, its target problems are identified:

- to develop students' ability to design digital technologies for developing their cognitive skills;
- to develop students' ability to design digital technologies for developing their creative skills;
- to develop students' ability to design digital technologies for developing their communicative skills;
- to develop students' ability to design digital technologies for developing their collaborative skills.

The *cognitive skills* are defined as an ability to conduct the cognitive activities, based on designing digital learning technologies in terms of opportunities of their implementation for developing dominant intelligence types and expanding the opportunities of non-dominant ones, which are typical for a certain intelligence profile, as well as to predict the further designing of digital technologies for the cognitive development of learning process participants.

The *creative skills* are interpreted as an ability to realize creative activities, based on designing digital technologies in terms of the opportunities of their implementation according to individual intelligence profiles and to predict the further designing of digital technologies for students' creative development.

The *communicative skills* are determined as an ability to use digital learning technologies for reception and reproduction of information messages while communicating with other people; to adhere to the ethics of network communication; to deepen knowledge about new digital technologies and the opportunities of their use to foster interpersonal interaction.

The *collaborative skills* are considered to be an ability to use digital technologies for providing the interaction with other people who, having different personal characteristics (age, gender, education, social status, experience, and professional

knowledge), are grouped together to fulfil a collaborative learning assignment; to support a positive emotional atmosphere while conducting group interpersonal activities.

The next component of the authors' model is the content-technological one which contains the universal and special digital learning technologies, whose choice is realized on the basis of the multiple intelligence theory by H. Gardner. According to this theory a personality has a number of intelligence types (logical-mathematical, verbal-linguistic, bodily-kinesthetic, visual-spatial, musical-rhythmic, intrapersonal, interpersonal, naturalistic). Each of them represents the special ways of processing and interpreting information messages, informing how a person learns the world.

Digital learning technologies are rapidly developing in both quantitative and qualitative aspects. For achieving the purpose and solving the target problems of the authors' model, two main groups of digital technologies are singled out: universal and special.

The *universal digital technologies* are regarded as learning technologies which can be used for activating the overwhelming majority of intelligence types (four intelligences and more) simultaneously. The universal digital technologies include: electronic social networks, multimedia presentations, game-based learning platforms, computer and video games, video conferences, digital narratives (storytelling) [16].

The *special* digital learning technologies are considered to be those which can activate one, two or three intelligences while being used. The special digital learning technologies include: chat, guest book, blog, forum, e-mail, photo, audio and video editors, resources for creating crosswords, rebus, augmented reality, spreadsheets, databases, online search tools for analysing and collecting data, online tools and applications, which design digital or printed graphic reproduction of time slots (timelines), etc.

The *operational-technological* component of the authors' model implies the realization of the process of teaching students to design digital learning technologies for developing the 21st century key skills in formal and informal education.

The procedure of designing digital learning technologies implies the definition of its opportunities for developing every student's cognitive, creative, communicative, and collaborative skills, depending on his or her unique intelligence profile. The choice of digital learning technologies in accordance to students' unique intelligence profiles is made in two ways. The first one includes the selection of technologies that can activate students' dominant intelligences; the other one is aimed at the compensating role of digital technologies; it means that a digital technology is chosen in the way that improves students' abilities in different types of activities which also require well-developed types of intelligences that are not dominant in this intelligence profile.

For example, if verbal-linguistic and visual-spatial intelligences are dominant for a student's intelligence profile, one should choose digital learning technologies that stimulate these intelligence types (digital narratives, text and graphic editors etc.). If it is necessary to make musical arrangement of information product, those digital technologies should be used that help students whose level of development of musical intelligence isn't high and increase students' expressive capacities.

Thus, digital learning technologies can perform the following functions: activating

and entertaining, activating and compensating.

The activating and entertaining functions are aimed at developing students' skills and abilities, contributing to activating dominant intelligences of an individual intelligence profile.

The activating and compensating functions can increase students' opportunities for creating information messages, strengthening and enabling the definition of this individual intelligence profile.

By combining different forms and methods of formal and informal education (lectures, seminars, laboratory works, trainings, discussions, projects, etc.), the open blended learning environment is developed that is characterized by high potential of developing students' cognitive, creative, communicative, and collaborative skills.

The *resulting* component of the authors' model is characterized by the development of digital competence that is distinguished by primary school pre-service teachers' ability to design digital learning technologies for developing cognitive, creative, communicative, and collaborative skills of all the participants of educational process.

The authors' model of designing digital learning technologies in primary school pre-service teachers' training belongs to individual learning models, as its developing and implementing are based on the idea of defining the opportunities for designing digital learning technologies in the educational process for developing every student's cognitive, creative, communicative, and collaborative skills, depending on his or her intelligence profile.

The model has a variable nature that is caused by the choice of digital learning technologies and has exactly defined characteristics, depending on the features and functions, defined for using digital learning technologies and a type of learning activities (see fig. 1).

Based on the conception and model, the methods of designing digital learning technologies in primary school pre-service teachers' training are developed.

The specificity of the methods is concretizing the choice of digital learning, based on the number of factors:

- a. defining by an educator a target problem on improving students' ability to design certain digital technologies for developing key skills;
- b. distinguishing students' individual intelligence profiles and, based on them, defining the activating and entertaining, activating and compensating functions of exactly chosen digital learning technologies;
- c. implementing project learning that has both monodisciplinary and interdisciplinary nature and is realized in such projects: "Interactive Book", "Interactive Poster", "Making Video Clips", "Prevention of Primary Schoolchildren's Computer Addiction", "Student Scientific Conference", etc.

The *target* component includes the improvement of students' abilities to design exactly chosen digital technologies for developing primary school pre-service teachers' cognitive, creative, communicative, and collaborative skills.

The *diagnostic-motivating* component implies the definition of students' intelligence profiles and their motives for using digital learning technologies in professional activities and in everyday life.

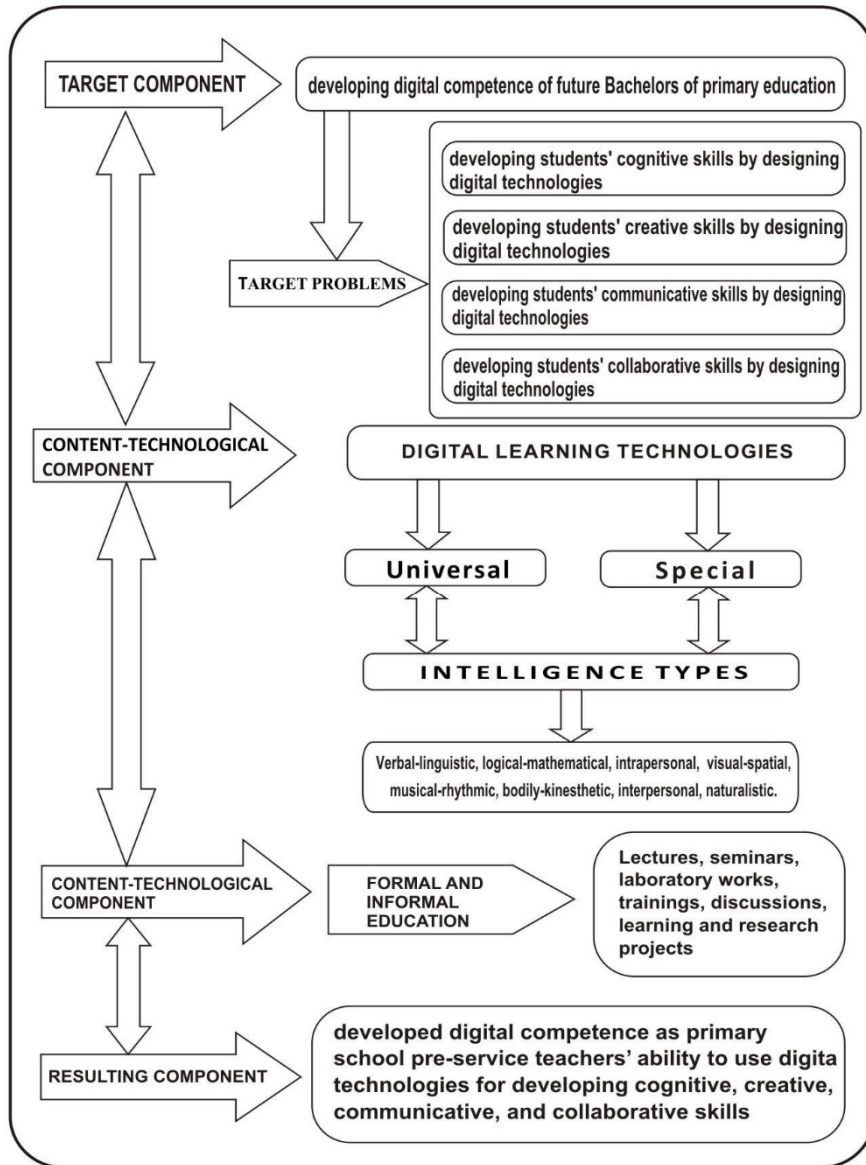


Fig. 1. The model of designing digital learning technologies in primary school pre-service teachers

The *content-technological* component involves creating learning content that is characterized by different digital learning technologies and their opportunities which contribute to developing cognitive, creative, communicative, and collaborative skills, as well as skills to act safely in information environment. The component contains the

characteristics of digital learning technologies which primary school pre-service teachers should use in educational process for developing different types of intelligence and key skills. While implementing different projects, a complex of universal and specific digital learning technologies is used, such as:

“Interactive Book” includes the use of universal (multimedia presentation and digital storytelling) and special (tools for online search, photo, video, audio, graphic and musical editors – by students’ own choice) digital technologies [17];

“Interactive Poster” is based on using multimedia presentation as a universal digital technology and a number of special digital technologies (tools for online search, photo, video, audio, graphic and music editors, resources for making crosswords, rebus, online tools and applications for digital or printed graphic reproduction of time slots (timelines) – by students’ own choice);

“Making Video Clips” requires the use of special digital technologies (tools for online search, photo, video, audio, graphic and music editors) and universal digital learning technologies – electronic social networks for disseminating the digital products;

“Prevention of Primary Schoolchildren’s Computer Addiction” is implemented by the use of universal digital learning technologies (multimedia presentation, digital storytelling, electronic social networks, game-based learning platforms, video conferences); as well a number of special digital learning technologies (e-mail, tools for online search, photo, video, audio, graphic and music editors, resources for making crosswords, rebus, etc.);

“Student Scientific Conference” is held on the basis of using universal digital learning technologies (multimedia presentation, digital storytelling, electronic social networks, video conferences) as well special digital learning technologies (e-mail, chats, tools for online search, text, photo, video, audio, graphic and music editors).

The *operational-technological* component is characterized by active forms and methods of learning, in particular, interdisciplinary project learning in formal and informal education.

The process of designing digital technologies for developing a digital learning resource that can be used in future teaching activities includes eight functionally interrelated stages:

1. Designing the project of digital learning resource, taking into consideration the learning content, students’ individual characteristics, their cognitive interests and needs and the definition of its teaching potential.
2. Choosing digital learning technologies for realizing the creative ideas according to the quality of digital learning resources, the development of digital skills and students’ individual intelligence profiles.
3. Making digital learning resources.
4. Sharing digital learning resources in the network and analysing their teaching potential, based on the proposals for improving their qualities.
5. Making necessary changes in digital learning resources.
6. Experimental implementation of digital learning resources in the practice and evaluating of its effectiveness.

7. The final designing of digital learning resources.
8. Making recommendations for its implementation.

The *resulting* component is defined by the development of digital competence as an ability to design digital learning technologies for developing cognitive, creative, communicative, and collaborative skills.

2. The **research stage** involves confirming, forming and controlling experiment (2014–2018) which provides for the experimental testing the effectiveness of the authors' model and methods of designing digital learning technologies in primary school pre-service teachers' training.

The research and experimental activities were held at the Faculty of Primary, Technological and Vocational Education at Donbas State Pedagogical University (Sloviansk, Ukraine). The research engaged 90 primary school pre-service teachers, aged between 19–29, who were gaining their first higher education in specialty "Primary Education".

The purpose of *confirming* experiment is to define the actual level of skills of future Bachelors of education to design digital technologies according to the criteria determined and to study the dominant type of intelligence.

The diagnostic of skills is conducted through the survey which includes self-assessment of the skills to design digital technologies for learning activities and everyday life.

The diagnostic of dominant types of intelligence is held, using the methods of defining the multiple intelligence of Walter L. Mckenzie, Jr.

The results prove that the dominant intelligence types of the majority of students, who are gaining the specialty "Music", are musical-rhythmic, intrapersonal and interpersonal. The dominant intelligence types of students of the specialty "Choreography" are bodily-kinesthetic, visual-spatial and interpersonal. The dominant intelligence types of students of the specialty "The English Language" are verbal-linguistic, interpersonal and intrapersonal. The dominant intelligence types of students of the specialty "Computer Studies" are logical-mathematical and interpersonal.

According to the results of the confirming experiment, the program of forming experiment is developed which implies practical implementation of methodical system of designing digital learning technologies. The activities are conducted within the courses "Information Technologies in Teacher Professional Activities", "Modern Information Technologies", "Foundations of Scientific Research", "Pedagogical Informatics" and others while realizing interdisciplinary projects, teaching practices and informal teaching activities in extracurricular work during four-year study.

The forming experiment is aimed at testing the research hypothesis about that the implementation of methodical system of designing digital learning technologies in training of future Bachelors of education ensures the improvement of the level of development of students' digital competence that contributes to enhancing their cognitive, creative, communicative, and collaborative skills.

The following target problems should be resolved during the formal experiment:

- to experimentally check the feasibility of implementing the methodical system of designing digital learning technologies in the process of primary school pre-service teachers' training;
- to study the influence of implementing the authors' methodical system and the development of students' cognitive, creative, communicative, and collaborative skills;
- to test the feasibility of the content and components of the methodical system in the process of primary school pre-service teachers' training.

3. The **controlling experiment** includes the diagnostic and analysis of the level of development of students' skills to design digital technologies, studying the dynamics of increasing the indicators of digital competence of future Bachelors of education to design digital learning technologies.

The criteria and indicators for testing the development of digital competence have been defined and described in details in our previous research [18].

4. **Processing and interpretation** of research data, making conclusions, making recommendations and defining the directions of further research (2018–2020).

3 Results

The results of the experiment, focused on training in designing digital learning technologies, are implemented in the development of digital competence as an ability to design digital learning technologies for developing primary school pre-service teachers' cognitive, creative, communicative, and collaborative skills, presented in comparative analysis of indicators, obtained at the initial and final stages of research (2018).

Comparing the development of pre-service teachers' skills to design digital technologies shows that at the initial stage of research 80% of participants have low or sufficient level and only every fifth has the high level. After implementing the pedagogical experiment, the distribution of students according to high, sufficient and low levels and criteria-based characteristics has significantly changed. The level of students (17,8%) has considerably increased, so the indicators of low level have significantly (twice) decreased, as well as indicators of the high level have improved (see fig. 2).

The least noticeable changes opposed to the other skills have been registered when comparing the indicators of the development of an ability to design digital learning technologies for improving creative skills. The quantitative indicators confirm the positive changes, but they are not so significant as, for example, results, gained while investigating cognitive skills. 4 students have upgraded their status (proceed to higher level), but this progress has been made by moving from the low level to the sufficient one. This fact proves the complexity of training to design digital learning technologies for developing creative skills (see fig. 3).

The conducted research gives us an opportunity to conclude that at the initial stage the majority of future Bachelors of education have low (17,8%) and sufficient (57,8%) level of development of an ability to design digital learning technologies for developing

communicative skills according to the criteria defined and every fourth of the students (24,4%) have high level.

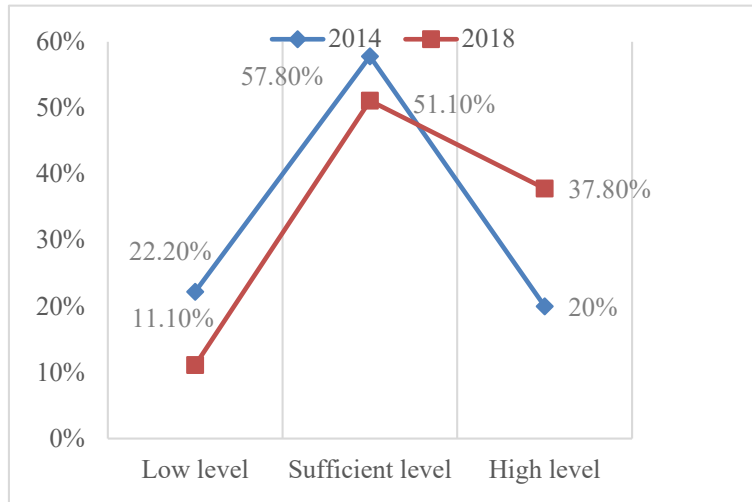


Fig. 2. Comparing the levels of the development of digital competence in designing digital technologies for enhancing cognitive skills in 2014 and 2018

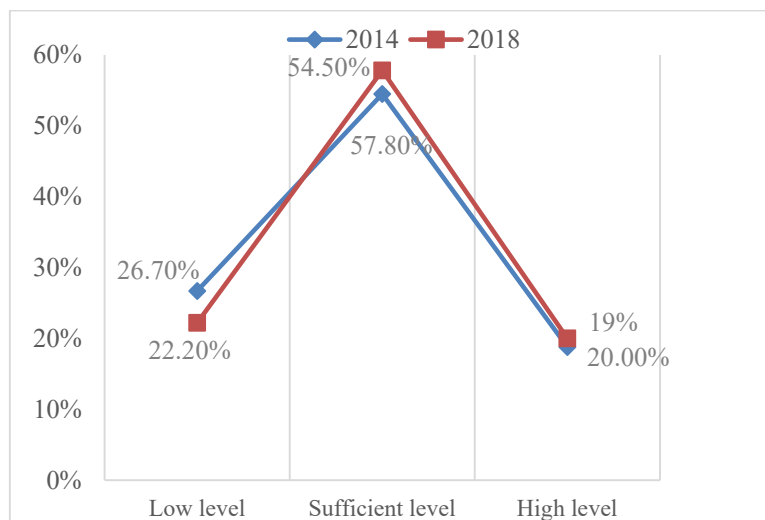


Fig. 3. Comparing the levels of the development of digital competence in designing digital technologies for enhancing creative skills in 2014 and 2018

The conducted research gives us an opportunity to conclude that at the initial stage the majority of future Bachelors of education have low (17,8%) and sufficient (57,8%) level of development of an ability to design digital learning technologies for developing

communicative skills according to the criteria defined and every fourth of the students (24,4%) have high level.

After conducting the pedagogical experiment, the distribution of the students according to low, sufficient and high level and criteria-based characteristics has significantly changed. The number of students, who have low and sufficient levels of communicative skills, have decreased by 5,6% and 3,3% respectively. So the number of students with high level has increased by 8,9% (see fig. 4).

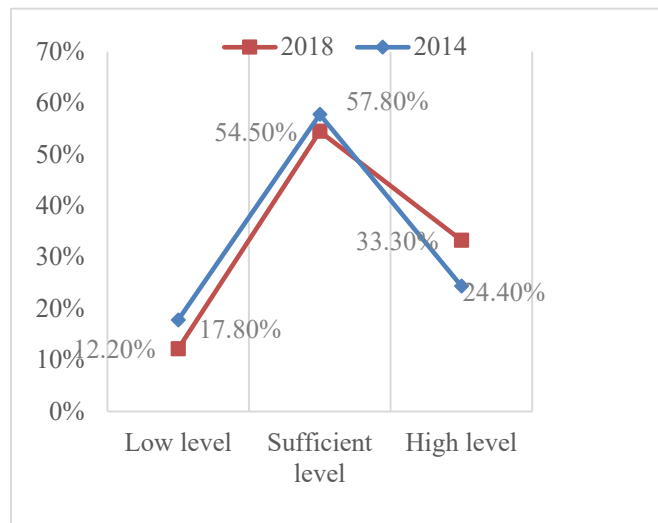


Fig. 4. Comparing the levels of the development of digital competence in designing digital technologies for enhancing communicative skills in 2014 and 2018

The results of research give us an opportunity to assert that at the initial stage of the research the majority of students (more than 75%) have not the skills to design digital learning technologies for developing skills to work efficiently in teams.

The implementation of the methodical system of designing digital learning technologies in training of future Bachelors of education contributes to improving the levels of development of an ability to design digital learning technologies for developing collaborative skills as 70% of students have achieved sufficient and high level, whereas the number of students with the high level has tripled (see fig. 5).

Thus, the main purpose of the experiment has been achieved as we gain comparative figures of the levels of development of digital competence of future Bachelors of education whose dynamics of changes is a reason to state the tendency of improving the effectiveness of educational process through implementing the methodical system of designing digital learning technologies.

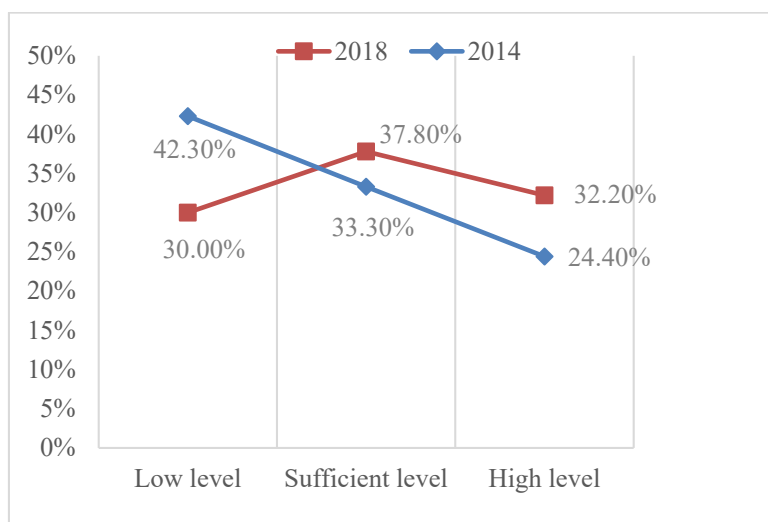


Fig. 5. Comparing the levels of the development of digital competence in designing digital technologies for enhancing collaborative skills in 2014 and 2018

4 Conclusions

In the article the methods of designing digital learning technologies in primary school pre-service teachers' training are substantiated and experimentally testified, which are aimed at using technologies for supporting the development of ways to perceive and produce information messages, improving cognitive, creative, communicative, and collaborative skills of all the participants of educational process.

The theoretical framework of the methods is the authors' conception of the feasibility of using the multiple intelligence theory by H. Gardner for choosing digital learning technologies, as their implementation creates conditions for developing all the types of intelligence, namely: logical-mathematical, verbal-linguistic, bodily-kinesthetic, visual-spatial, musical-rhythmic, intrapersonal, interpersonal, and naturalistic.

For studying the opportunities of reproducing the authors' conception in the educational process, the model is developed, whose specificity is explained by the fact that the blended learning environment is developed due to training primary school pre-service teachers to design digital learning technologies. In this environment the abilities of every participant are revealed, critical thinking, creativity, communicability, and collaborativity – the key skills of modern people – are developed.

The authors' model to design digital learning technologies in primary school pre-service teachers' training belongs to innovative individualized learning models. It has also interdisciplinary and variable character, as well as it gets certain features according to the specificity and functions, provided for using digital learning technologies and types of learning activities.

Based on the conception and model, the methodical system for designing digital learning technologies in primary school pre-service teachers' training is developed.

The methodical system includes five interrelated components: target, diagnostic-motivating, content-technological, operational-technological and resulting ones. The structure of each component is defined by the content of target problems, type of students' individual intelligence profiles, monodisciplinary or interdisciplinary character of project learning.

The dynamics of changes and gained comparative figures of the development of digital competence of future Bachelors of education are the reasons to state about the tendency of improving the effectiveness of educational process through implementing the methodic system of designing digital learning technologies.

In our opinion, the opportunities of designing digital technologies for developing citizens' competences in conditions of informal education requires the further research.

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Minimalism in Designing User Interface of the Online Platform “Higher School Mathematics Teacher”

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Abstract. The article addresses the issue of minimalism in User Interface (UI) design of online courses. The paper debates the latest researches related to UI design, the quality of which influences the success of educational platforms. The analysis, which we carried out, allowed us to focus on such minimalism criteria of online courses that provide students’ satisfaction with online education. The research considers the design tools that are used to achieve minimalistic UI of mathematical and methodical courses on the platform “Higher School Mathematics Teacher”. The article discusses the creation of a minimalistic UI model and web tools search to develop it. During the survey, the answers, which were given by 203 volunteers, who became the first users of platform courses, allowed determining the directions of interface improvement on the platform “Higher School Mathematics Teacher. The received average estimate confirmed the interface minimalism of the online courses published on the platform “Higher School Mathematics Teacher”.

Keywords: User Interface of online courses, minimalism principles, design tools, Web design elements: accordions, tabs, sliders.

1 Introduction

1.1 Problem statement

Before creating a website that will correspond to the user’s needs, the question of developing a web page arises among specialists. Their minimalism is among the latest trends that web page design experts consider. Moreover, studying strategies that influence User Interface (UI) developments, studios Acodez [1], Nielsen Norman Group [2], WebsiteBuildErexpert [3], TheNextWeb [4] indicate that minimalism is

something users prefer first. Experts warn that involving an excessive number of technologies decreases the chances to involve customers to the web product. Mathematics teacher is a serious demanding client who is well oriented in the modern web design market. That is why the issue of involving minimalism in designing UI of the online platform “Higher School Mathematics Teacher” [5] is actual, following which concept [6], represents online mathematics and methodical courses, that are used by both mathematics teachers and students who master the pedagogical profession.

1.2 Analysis of recent research papers and publications

The conclusions in the research made by Ahmad Tajudin Baharin et al. [7] confirm that interface design of online courses is as important as the content and educational method choice. While analyzing UI design directions, the scientists proved that its quality influences the success of a separate course and an educational platform as a whole.

Nowadays UI designers point out minimalism as one of the main web design trends that are used while developing structures and content of the online course. Scientists also discuss this trend in their researches. Colleen Carraher Wolverton and Brandi N. Guidry Hollier [8] describe the survey among university teachers concerning the involvement of a minimalistic approach to the course development. The authors of the article believe that it is necessary to use fewer technologies, use and simplify the education, necessary for teaching an online course, emphasizing that the course should be simple. Somayeh Mehrizi Sani and Yeganeh Keyvan Shokooh [9] highlight that minimalism with unnecessary aspects elimination and visual elements organization leads to the audience confusion decrease and increase of efficient interaction with the web site. In order to determine and prove the factors that influence teachers’ satisfaction with their studies on the Internet Doris U. Bolliger and Oksana Wasilik [10] developed a web survey that they used to estimate the acquired teachers’ satisfaction in the context of online educational environment. While describing respondents’ answers the scientists pointed out that minimalism principle use allows making an online course graphically simple. In its turn, university teachers who worked with the course indicated that purely efficient design helps them not to get distracted by the presentation during the course. While studying minimalistic documentation strategies and their successful use to create short videos, Ehren Helmut Pflugfelder [11] offered an instruction considering minimalism in web applications. Ard W. Lazonder [12] also points out the importance of developing such instructions and specifies that in order to create a minimalistic interface, web developer has to post the elements strictly showing only those which have the highest importance and do not distract users from the important part. While estimating the positive and negative interface influence of online developments on educational process Jose María del Campo et al. [13] carried out a research User eXperience (UX) using a qualitative analysis of students’ surveys studying the level of their satisfaction with web page use. Kristen Suzanne Betts [14], Doris U. Bolliger and Trey Martindale [15], Judith V. Boettcher [16], Diane M. Bender et al. [17], Doris U. Bolliger and Oksana Wasilik [10] studied the factors to determine students’ satisfaction with online development. Among the factors that explain students’ satisfaction with online courses, scientists point out: intuitively clear

navigation system and free space on course pages, page download speed on the platform, easy navigation and easy access to the necessary educational content, involving an insignificant number of interactive web design elements.

Therefore, the analysis of the above-mentioned papers helped to determine the goal of this research. It became the search for web tools to develop a minimalistic UI model, the use of which allows making online courses on the platform “Higher school Mathematics Teacher” graphically simple and accessible for users.

2 Method

When we studied the question of the minimalistic UI use while developing UI online courses we analyzed several Mathematics courses published on the educational platforms Prometheus [18], Edera [19], EDUGET[20], iLearn [21], Coursera [22] and The Open University [23].

While analyzing the courses of the above-mentioned platforms we considered the User Interface correspondence of these courses to the modern web design trends and determined in Table 1 the types of interactive elements that are the most used to implement the minimalism concept.

The Deductive Approach to Content Analysis of Mathematics courses helped to choose the popular elements that are used in web design to achieve minimalism. The navigation implementation in most analyzed courses is carried out using accordions that enable not to overload users with minor information having access to the educational content. Besides, on Prometheus [18], Edera [19], EDUGET [20] and The Open University [23] platforms, tab navigation is used. In the design of educational online courses published on the platforms Edera [19], iLearn [21] and Coursera [22] sliders are used to systematize text or graphic information.

Therefore, the results of the carried analysis ensured the use description of accordions, tabs, and sliders.

2.1 “Accordion” element use

The graphic interface element “accordion” is used when it is necessary to structure the content. It looks like a vertically or horizontally built set of elements that have a text mark or draft and the main part. Every element can have two states – hidden or open. These states are responsible for the visual feature of the main element part. The change of these states is implemented by clicking on the text mark or draft. Usually, at a certain point, only one “accordion” element is active, it deactivates when you choose another element or double click on the current element. While using “accordions” you can get a convenient view of the complex elements’ hierarchy, as this interface element can fold one into another. Therefore, “accordions” use in UI design enables to follow minimalism postulates and not to overload users with minor information.

“Accordions” integration in the online course allows implementing a convenient structural system of content compilation, since, usually, an online course includes sections, topics, subtopics, and subsections. “Accordions” use enables the participants

to navigate easily through the online course, choosing one or another element of its structure.

Table 1. Use of the most used interactive elements to implement the minimalism concept in mathematical courses on educational platforms.

Online courses	UI minimalism implementation tools		
	“Accordion” element use	Slider use	Tab use
Data analysis and statistic conclusion using R language [24]	Is not used	Is not used	For the content division of every course chapter into sections
Algorithms development and analysis [25]	Is not used	Is not used	For the content division of every course chapter into sections
Mathematics: Arithmetic, equations and inequalities [26]	For course content structuring and navigation implementation	For educational material presentation	For the content division of every course chapter into sections
Solid geometry [27]	For navigation implementation	Is not used	For course navigation implementation
Derivative and integral. Combinatorics and probability [28]	For course content structuring and navigation implementation	Is not used	For course navigation implementation
Mathematics. Simple [29]	Is not used	For text information systematization	Is not used
Matrix Algebra for Engineers [30]	For course content forming and navigation implementation	For educational material presentation	Is not used
Advanced Linear Models for Data Science 1: Least Squares [31]	For course content navigation implementation	For theoretical material presentation	Is not used
Mathematics for Machine Learning: Linear Algebra [32]	For course content navigation implementation	For graphic information systematization	Is not used
Mathematics for science and technology [33]	For course content structuring	Is not used	For navigation implementation through course sections
An introduction to complex numbers [34]	For forming structured course content and navigation implementation	For text information systematization	For navigation implementation through course sections
Using numbers and handling data [35]	For forming structured course content and navigation implementation	For theoretical material presentation	For navigation implementation through course sections

There are several approaches to create “accordions”. Let us point out the main ones.

1. “Accordion” program implementation through cascading style sheets (CSS) using script programming language JavaScript. This approach implies the content structure creation in HTML format, CSS stylization and interactivity implementation using jQuery library. Nowadays, “accordion” implementation is simplified because it has already been created and integrated into a big number of front-end frameworks such as React.js, Angular, Vue.js, Bootstrap, etc. It enables to create “accordions” without writing JavaScript code.
2. Using program libraries of front-end frameworks. If the front-end framework is used while creating a platform for online courses, there is a possibility to use ready libraries for “accordions” implementation. For instance, there is Gentelella library for Yii2 framework, Material Dashboard library for Laravel framework.
3. Using “Content Management Systems” (CMS) plugins. For instance, if CMS systems are used to create platforms for online courses, it is possible to connect the ready plugins of this system. For example, for CMS WordPress there are plugins to create Accordions Tables, Accordion FAQ, Easy Accordion, etc. On the platform “Higher School Mathematics Teacher” [5] we used the plugin “Responsive Accordion and Collapse”, that includes a set of the main tools to create accordions. The main advantages of using plugins are flexible settings of accordion look, ensuring convenient data entry and content editing, published in accordion sections.

2.2 Sliders use on pages of educational online courses

Slider is a web design element that includes a block of a certain length, the main function of which is a consistent image (or other content) change.

Using sliders on pages of educational online courses allows providing users with the necessary information without scrolling the page. Moreover, sliders enable us to save space and not to visually overload the web page.

In general, sliders have a minimalistic design and consist of the following elements: navigation tools, a screen, and markers with the information on the slide number. Some sliders can contain miniatures of other slides, a timer with the slide change time and they can predict a possibility to pause when you hover the cursor over the current slide.

Slide change takes place in the automatic, manual and mixed mode. The mode choice depends on the functional slider’s purpose within a particular online course.

Sliders are implemented using JavaScript technologies. Each of them is based on HTML-code. In most cases, constructions of such types are created using jQuery library that includes a significant number of standardized objects to create sliders of different types, forms, and content. In functions that are responsible for the slider’s work, slides’ turning speed is indicated, presentation conditions of previous/ following slides are given, and visual slides’ presentation and turning effects are set. At the same time, HTML-code is responsible for slides “bringing” in the necessary web page place, CSS – for the slider look, JavaScript – directly for the slider’s work, in particular, jQuery library functions.

While integrating sliders on the pages of “Higher School Mathematics Teacher” platform to represent educational content we use the manual mode of slides change. Sliders are created using WordPress plugin “Elementor” and are completely adaptive.

Nowadays there are plenty of plugins to create sliders, in particular, MetaSlider, Master Slider, Slider Pro, etc.

2.3 Using tabs as the best navigation option

One of the most popular elements that are used in web design to achieve fast and interactive content presentation is tabs. Tabs are web interface element that consists of a headline and hidden content that becomes available referring to the headline.

Tabs are used to divide the content into sections. It facilitates saving space on the screen and simplifies users' access to the necessary content. The content should be divided into parts in order to look logical, expected and clear for users.

Tabs use as a navigation system on pages of online courses is relevant when there are from 2 to 9 categories of educational content that can fit in one line. For online courses of the platform "Higher School Mathematics Teacher", which includes from 3 to 6 sections, the tabs use is one of the best navigation options.

When integrating tabs on web pages it is necessary to consider the fact that the number of categories should not be often changed, the text on the tabs should be logical and substantial. The chosen tab should stand out, defining the user's location now. It is not recommended to include the navigation with tabs in the design in case users need to have a simultaneous content comparison, as tabs navigation will overload the memory, significantly increasing cognitive load.

While using tabs it is necessary to avoid overloading web pages during windows changing, as it significantly slows down the navigation between tabs. Distant content downloading using Ajax can be one of the options that are used for the dynamic information published on the external server. In this case, it is relevant to use JavaScript.

The carried analysis using interactive elements helped us to develop a minimalistic UI model of online courses on the platform "Higher School Mathematics Teacher" (Figure 1).

3 Results

In order to carry out the User Interface relevance level analysis of online courses [43-46] published on the platform "Higher School Mathematics Teacher" [5] to the minimalistic web design principles, we held a survey among platform users. Respondents were offered to go through the survey using the form developed through Survio service [36], which enables a survey creation, their integration on web pages and received data analysis. In order to get a greater number of answers, we posted the created survey on the forum of the platform "Higher School Mathematics Teacher" through iFrame implementation.

203 respondents took part in the survey. We were interested in teachers' and students' opinion who became the first platform users. These were the representatives from Donbas State Engineering Academy, Donbas National Academy of Civil Engineering and Architecture, Institute of chemical technologies of Dahl East Ukrainian National University (the town of Rubizhne), Kryvyi Rih State Pedagogical

University. We offered them to range the correspondence criteria of the developed online courses interface to the minimalism principles on a scale from 1 to 5 where 1 is a minimal parameter estimate and 5 is maximal. Volunteers' responses analysis is represented below.

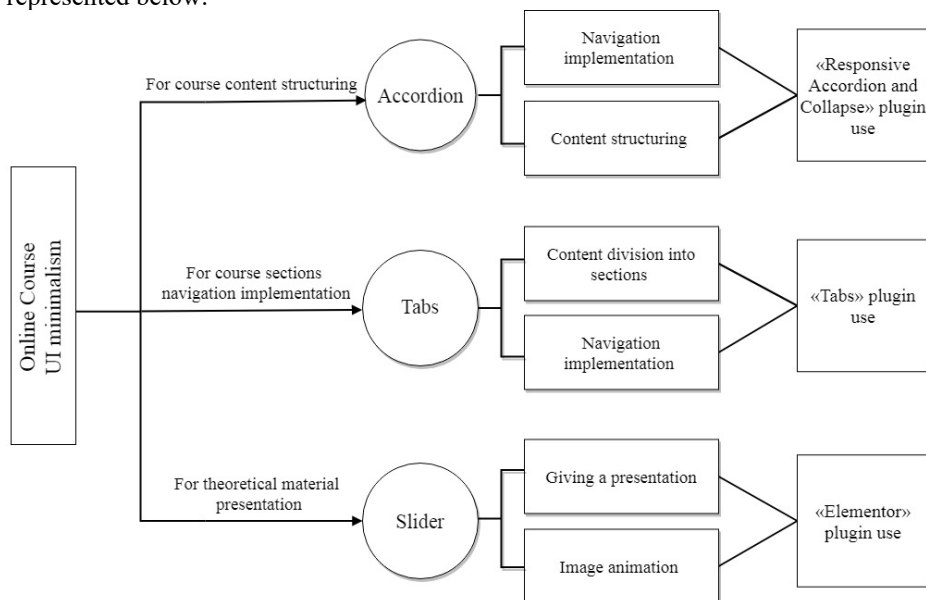


Fig. 1. Minimalistic UI model of online courses on the platform “Higher School Mathematics Teacher”.

So, according to the survey results (Figure 2), 40,9% of respondents totally agree with the fact that the navigation system on course pages is simple and intuitively clear, 27,3% agree, 20,5 % rather agree, 9,1% rather do not agree with this statement and 2,3% of respondents believe that the navigation system is complicated and unclear. Besides, in most platform users' opinion, the elements on course pages are strictly structured (Figure 3).

The survey results on page download speed on the platform are the same. 43,5% of respondents chose the variant “excellent”, 34,8% – “good”, 10,8% think that download speed is satisfactory, 8,7% – sufficient and 2,2% pointed out that pages download too long.

The survey results of free space on course pages (Figure 4) showed that practically a quarter of the respondents do not agree with this statement. As free space is one of the most important principles of minimalistic design, the received result indicates the necessity to improve the interface following this direction.

According to the navigation ease on course pages, it is pointed out (Figure 5) that 42,9% of respondents easily navigate on the page, 28,6% chose the variant “good”, 16,7% think that navigation ease is satisfactory, 9,5% – sufficient, and 2,4% highlighted that it is quite difficult to navigate on the page. Thus, the received answers proved the

absence of users' overload with minor information on the course pages, which is one of the key principles of minimalistic design.

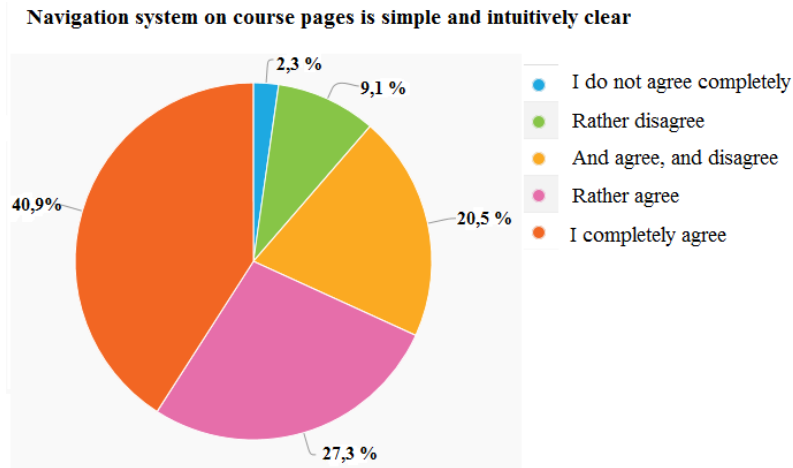


Fig. 2. Ranging respondents' opinion on the navigation system of online courses on the platform.

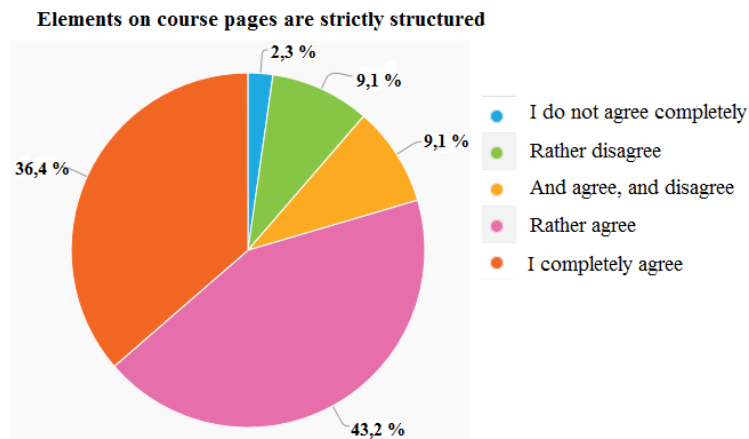


Fig. 3. Ranging platform respondents' opinion on elements ordering on course pages.

While estimating easy access to the necessary educational content during the course, 42,9% of respondents put the mark "excellent", 35,7% – "good", 7,1% – "satisfactory", 11,9% – "sufficient", 2,4% – "unsatisfactory". The results of estimating logic and comprehensibility to represent educational content are practically identical. 88,1% of respondents are satisfied with the content presentation, 11,9 % of respondents believe that logic and comprehensibility do not correspond to their requirements. Also, 76,2 % of respondents confirmed that clear headlines are used on online course pages. 71,8% of users indicated that an insignificant number of interactive elements are present on

course pages, 13% rather agree with this statement and 15,2% point out the necessity to improve the pages regarding the involvement of interactive web design elements.

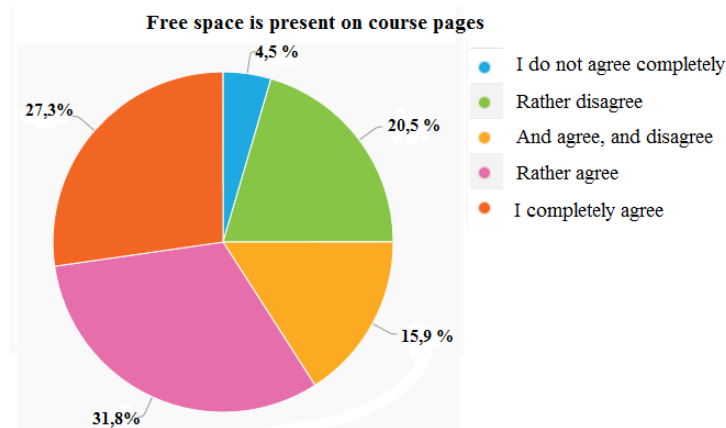


Fig. 4. Ranging respondents' opinion about free space on course pages.

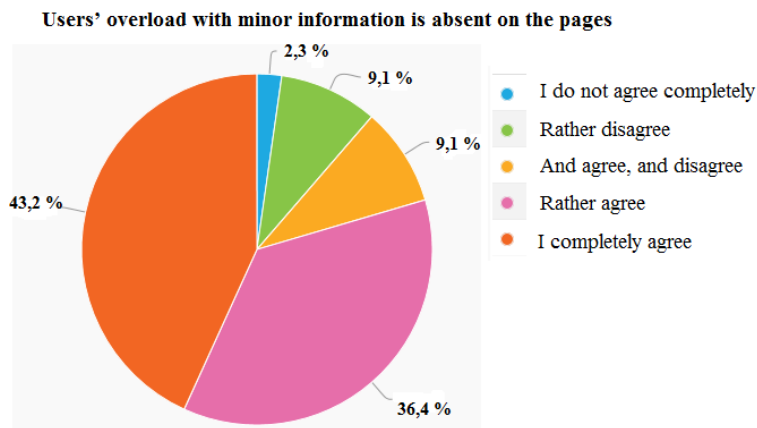


Fig. 5. Ranging respondents' answers on users' overload with minor information.

To verify the internal consistency of the survey results we calculated the Cronbach's Alpha by the formula:

$$\alpha = \frac{k}{k-1} \left(1 - \frac{\sum S_i^2}{S_T^2} \right)$$

where k – the number of criteria included in the survey; S_i – the mean-squared departure of the i -th criterion ($i=1, \dots, k$); S_T – the mean-squared departure of total indicators for all survey criteria.

As a result of the calculation <https://drive.google.com/open?id=1HK5X0aJUNdC7g9ytSgrwRpVzHlo5kvNt>, we got the value $\alpha = 0,713$, indicating a sufficient level of internal consistency.

Following the survey results, an average estimate of the given criteria implementation quality was calculated and is represented in table 2.

Table 2. The average estimation of minimalism criteria implementation quality on the online platform “Higher School Mathematics Teacher”.

Criterion	Average estimation
1. Easy, intuitively clear navigation system	3,97
2. Strictly structured elements	4,03
3. Page download speed	4,03
4. Free space on the page	3,68
5. Easy navigation on the page	4,09
6. Absence of users’ overload with minor information	4,05
7. Easy access to the necessary educational content	4,07
8. Logic and comprehensibility of content presentation	4,1
9. Headlines clarity	4,02
10. An insignificant number of interactive elements on the page	3,88
Total average estimation	3,992

After getting a total average estimate of 3,992, we conclude that the interface of online courses published on the platform “Higher School Mathematics Teacher”, can be called minimalistic. Additional improvement requires sticking to the criteria on free space and involving an insignificant number of interactive elements on course pages.

4 Discussion

Hans van der Meij and John M. Carroll [37] defend the minimalistic approach as a better method to develop education and provide information. Hartmut Obendorf [38] emphasized that minimalism becomes an important tool that helps to visualize the simple thing. The scientist defined minimalism types for the interaction design of educational process participants, and he discusses the tools for different forms of design minimization. Papia Bawa [39] highlighted the minimalism advantages from a technical point of view as a faster page download and better compatibility using screens of different sizes. Therefore, scientists’ research proved our opinion about the actuality of researching minimalism in designing user interface on the online platform “Higher School Mathematics Teacher”.

The opinion given by UI-designers, back-end developers of studios Turum-burum [40], University Teaching & Learning Center [41], Neo Blog [42], Campus Technology [16] and the Deductive Approach to Content Analysis of mathematics courses on well-known online platforms [18-23] described the implementation of accordions, tabs, and sliders that are used in web design to achieve minimalism. The analysis of the indicated web design elements helped to develop the model (Figure 1), during the creation of which we concentrated our attention on such UI minimalism criteria of educational online courses as free space on course pages, minor information on course pages, intuitively clear navigation system and page download speed. During the platform

users' survey, we concentrated on the verification of how the offered criteria are followed on the pages of the courses that are published on the platform.

Based on the carried research we developed a minimalistic UI model of the platform online courses that reflects: elements providing minimalism, elements functions that allow ensuring minimalistic UI criteria, plugins to create web design elements. Model functioning ensures navigation implementation on course pages, content structuring with its division into sections, giving presentation and image animation.

5 Conclusions

Resource and scientific research analysis proves the necessity to follow minimalism principles while developing an online course of the platform "Higher School Mathematics Teacher". We relied on the resource and scientific research analysis that gives recommendations on the minimalism criteria development and offered a group of criteria that ensure easy understanding of the course material, do not overload users with minor information, and make navigation on course pages easy and accessible.

We offered to range the developed course interface following the criteria of minimalism principles to estimate UI minimalism of platform educational online courses. After getting a total average estimate of 3,992 on UI minimalism criteria implementation quality from the respondents, we concluded that the developed course interface on the platform "Higher School Mathematics Teacher" can be considered minimalistic. The improvement of the received average result is possible on condition that the interface, which ensures sufficient free space on course pages according to the developed a minimalistic UI model of online courses on the platform "Higher School Mathematics Teacher", is improved. Therefore, we connect further research with the User Interface platform improvement according to the minimalism principle and quality typography use, as the latter one improves material readability, increases the information perception level, influences educational material learning level.

6 Acknowledgments

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Selection of Mobile ICT for Learning Informatics of Future Professionals in Engineering Pedagogy

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Abstract. The research aims to theoretically justify and experimentally verify selection of mobile ICT for learning informatics to future professionals in engineering pedagogy. The research tasks include selecting groups of informatics subjects and mobile ICT tools for learning future professionals in engineering pedagogy. The research object involves selection of mobile ICT for the training process. The re-search subject is selection of mobile ICT for learning informatics to future professionals in engineering pedagogy. The research results imply analysis of the national and foreign researches into mobile ICT for learning informatics. The latest publications concerning selection of mobile ICT for teaching Informatics subjects (Mobile Learning Management Systems, Mobile Modeling and Programming Environments, Mobile Database Management Systems, Mobile Multimedia Authoring Tools, Audience Response Systems) are analyzed. Informatics subjects are united into 19 groups, mobile ICT tools – into five groups. The experimental research is conducted according to the syllabuses for Speciality 015.10 “Professional Education (Computer Technologies)”. The expert assessment results for each of the content blocks of informatics subjects allow determining leading and auxiliary mobile ICT teaching tools.

Keywords: Mobile ICT, Mobile Learning Management System, Mobile Modeling and Programming Environments, Mobile Database Management Systems, Mobile Multimedia Authoring Tools, Audience Response Systems, Learning Informatics, Engineering Pedagogy.

1 Introduction

Pedagogical practice has accumulated sufficient experience of arranging the training process through distance learning technologies, mobile ICT being one of them. Application of mobile ICT provides students with access to educational resources anytime anyplace, enhances efficient organization of students’ in- and out-of-classroom

activities through making training continuous and mobile, increasing the part of out-of-classroom work controlled by the teacher and creating conditions for integrating various forms of training [13, 15, 18]. Mobile ICT are aimed at supporting personality-oriented training. So, mobile ICT applied to teaching Higher Mathematics at technical universities provides students with an opportunity to watch training materials before doing a module or examination paper, look through lecture materials before practical classes, get responses to one's answers in class, maintain feedback with the teacher and other students, consult with the teacher and do assignment in mobile middleware [13].

Unlike distance learning, mobile learning is more accessible for most students, while mobile learning ICT are quite flexible to be used for supporting traditional learning [21].

Steffen Kersten analyzes approaches to further education in the field of engineering pedagogy for the development of qualifications for the design of teaching and learning processes in engineering education. He line, that quality management systems at German universities have increasingly focused their attention on the further pedagogical training programs for engineer-pedagogy [9].

In paper [11] described mobile ICT-enabled and collaborative learning opportunities for students. The research component of the project was designed to explore the adoption of video-conferencing technology and other collaborative Information and Communication Technologies (ICT) amongst educators. Authors develop purpose needs of in-service teachers necessary to enable them to organize video-conferencing based learning events.

Nina Tvenge and Kristian Martinsen in the research on selection of ICT-tools for manufacturing education, described that administration has had great influence on what tools were selected for teaching processes organization, and that this has led to both increased use and non-use of ICT in their teaching practice. However, authors noted that ICT for teaching is an enabling technology with a possibility for increased learning outcome in engineering education [19].

Cristopher J. Devers and Stefanie Panke, showed up an overview of learning with mobile ICT. The author provides a condensed overview of learning with mobile devices in higher education, and offer summaries of the relevant research for e-books, podcasts, audience response systems, and augmented reality, as related to mobile devices. The author suggest that technology is simply a medium or tool, and that future research should explore how mobile devices can support learning with evidence-based practices and Mayer's 13 principles of multimedia learning [4].

By selection of mobile ICT for learning informatics we have analyzed the latest publications on the following tools:

- Mobile Learning Management Systems in learning process researched by Luisa Sanz-Martínez, Erkan Er, Alejandra Martínez-Monés, Yannis Dimitriadis and Miguel L. Bote-Lorenzo [14], Valerii Yu. Bykov [2], Insook Han and Won Sug Shin [8];
- Mobile Modeling and Programming Environments are described by Badreldin Altayeb and Kostadin Damevski [1], Francesc-Josep Lordan Gomis [10];

- Mobile Database Management Systems researched by Deniz Mertkan Gezgin [6], Minzhe Guo, Kai Qian and Li Yang [7], Milan Eric, Slobodan Mitrovic, Miladin Z. Stefanovic and Aleksandar Djordjevic [5];
- Mobile Multimedia Authoring Tools have been reviewed by Yuliia V. Yechkalo, Viktoriia V. Tkachuk, Tetiana V. Hrunтова et al. [20], Dian Tjondronegoro [17], Andrii M. Striuk, Maryna V. Rassovytska, Svitlana V. Shokaliuk [16];
- Audience Response Systems have been researched by Tan Fung Ivan Chan, Marianne Borja, Brett Welch and Mary Ellen Batiuk [3], Dylan M. Moorlegghen, Naresh Oli, Alison J. Crowe, Justine S. Liepkalns, Casey J. Self and Jennifer H. Doherty [12].

2 Purpose

The research is aimed to theoretically ground and justify the selection of mobile ICT for learning informatics to future professionals in engineering pedagogy.

3 Results

To determine significance of mobile ICT application to teaching Informatics subjects, the survey Significance of application of mobile ICT to teaching Informatics to future professionals in engineering pedagogy of Speciality 015.10 “Professional Education (Computer Technologies)” was conducted (Fig. 1, available at <http://goo.gl/CVsXcl>). Eleven respondents from the University teaching staff were asked to assess efficiency of using mobile ICT by the 5-point quality scale (from 1 – inadvisable to use to 5 – advisable to use):

- Mobile Learning Management Systems (Moodle, Claroline, eFront, etc.);
- Mobile Modeling And Programming Environments (Web-environments to model and conduct researches like CoCalc, HPCCloud; online-IDE like Cloud9 IDE, PythonAnywhere, Eclipse Che, Pascal/C++/PHP Online, etc.);
- Mobile Database Management Systems (InterBase, SQL Anywhere, Microsoft SQL Server, IBM DB2 Everyplace, Oracle Database Lite, SQLite, etc.);
- Mobile Multimedia Authoring Tools (audio- and video-services like YouTube, Vimeo, etc.; online presentation editors like Prezi, Google Slides, etc.; animation editors like VideoScribe, etc.; graphical editors and augmented reality tools like Paint 3D, SketchUp, etc.);
- Mobile Audience Response Systems (Google Forms, EasyTestMaker, Online Test Creator, etc.) [18].

Informatics subjects using mobile ICT were united into 5 content blocks:

1. Theoretical principle of Informatics:

- 1) Discrete Programming, Operation Research, Computer Logic, Theory of Automatic Control;
- 2) Computer Cryptography;

2. Architecture of modern computing machines:
 - 3) Architecture of Computer Systems and Networks, Microprocessor Systems;
3. Basics of algorithmization and programming:
 - 4) Basics of Algorithmization and Elements of Programming;
 - 5) Visual Programming;
 - 6) Low-Level and Systems Programming;
 - 7) High-Level Programming Language;
 - 8) Web Programming;
 - 9) Software Design Technologies;
 - 10) Database Programming;

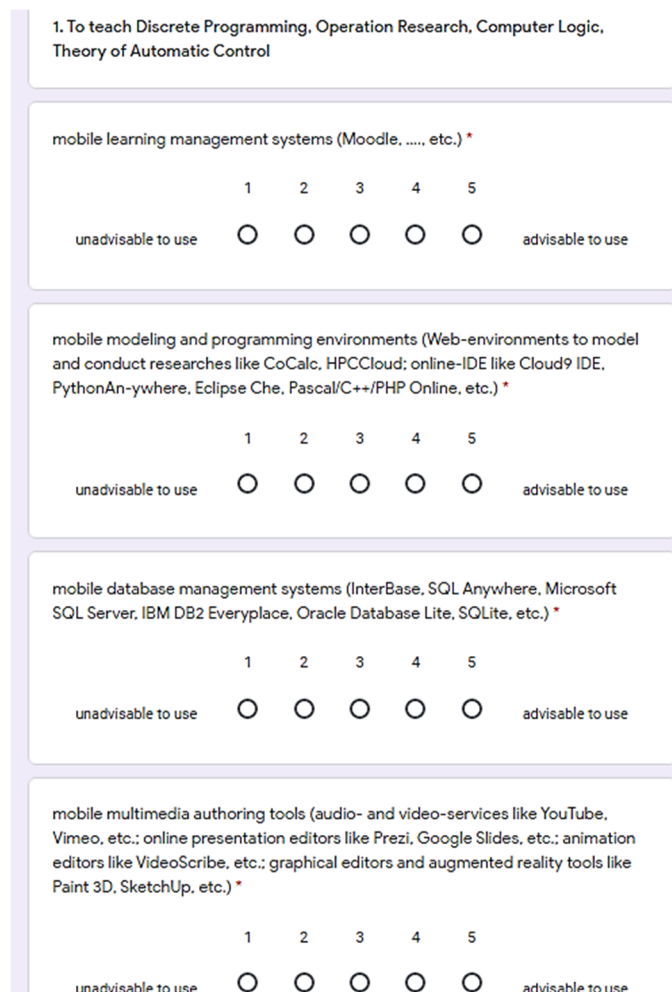


Fig. 1. Significance of application of mobile ICT to teaching Informatics to future professionals in engineering pedagogy of Speciality 015.10 “Professional Education (Computer Technologies)”

4. Software of computing systems:
- 11) Project Management;
 - 12) Application Software;
 - 13) Systems Software;
 - 14) Basics of Information Security;
 - 15) Computer Design and Multimedia;
 - 16) Engineering and Computer Graphics;
 - 17) Computer Aided Design;
5. Computer technologies in professional activity of professionals in engineering pedagogy:
- 18) Automation Systems for Document Management;
 - 19) Computer Pedagogical Technologies, Computer Ergonomics.

Table 1 presents assessment of efficiency of applying each of five tools for the 19 groups of Informatics subjects grouped into five basic content blocks.

Table 1. Assessment of efficiency of applying mobile ICT to teaching Informatics subjects to future professionals in engineering pedagogy, Speciality 015.10 Professional Education (Computer Technologies)

Content block	Group of Informatics subjects	Mobile ICT tools					Average efficiency estimate for subject group
		mobile learning management systems	mobile modelling and programming environments	mobile database management systems	mobile multimedia authoring tools	mobile audience response systems	
<i>Theoretical principle of Informatics</i>	Discrete Programming, Operations Research, Computer Logic, Theory of Automatic Control	4.09	4.36	3.27	4.18	4.45	4.07
	Computer Cryptology	4.00	4.00	3.36	4.00	4.18	3.91
<i>Architecture of modern computing machines</i>	Architecture of Computer Systems and Networks, Microprocessor Systems	4.09	3.55	3.00	4.09	4.27	3.80
<i>Basics of algorithmization and programming</i>	Basics of Algorithmization and Elements of Programming	4.27	4.45	3.27	4.36	4.36	4.15
	Visual Programming	4.09	3.91	2.73	4.36	4.18	3.85

Content block	Group of Informatics subjects	Mobile ICT tools					Average efficiency estimate for subject group
		mobile learning management systems	mobile modelling and programming environments	mobile database management systems	mobile multimedia authoring tools	mobile audience response systems	
	Low-Level and Systems Programming	4.00	3.91	3.00	3.91	4.09	3.78
	High-Level Programming Language	4.09	4.45	3.55	4.27	4.18	4.11
	Web Programming	4.27	4.36	3.55	4.18	4.36	4.15
	Software Design Technologies	4.09	4.45	3.64	4.18	4.27	4.13
	Database Programming	4.09	4.27	4.82	4.09	4.27	4.31
<i>Software of computing systems</i>	Project Management	4.09	2.82	2.82	4.09	4.27	3.62
	Application Software	4.36	2.91	3.09	4.27	4.45	3.82
	Systems Software	4.09	3.45	3.18	3.91	4.27	3.78
	Basics of Information Security	4.09	3.00	3.09	4.00	4.27	3.69
	Computer Design and Multimedia	4.18	3.64	2.64	4.73	4.36	3.91
	Engineering and Computer Graphics	4.09	3.00	2.55	4.91	4.55	3.82
	Computer Aided Design	4.18	3.45	3.09	4.18	4.36	3.85
<i>Computer technologies in professional activity of professionals in engineering pedagogy</i>	Automation Systems for Document Management	4.27	3.36	3.45	4.09	4.36	3.91
	Computer Pedagogical Technologies, Computer Ergonomics	4.36	2.91	2.91	4.64	4.82	3.93
Average efficiency estimate of the tool		4.15	3.70	3.21	4.23	4.33	

After averaging, the obtained results ranged from 2.55 (application of mobile data-base management systems while studying the subject Engineering and Computer Graphics) to 4.91 (application of mobile multimedia authoring tools while studying the subject Engineering and Computer Graphics).

Numeric values were transformed into qualitative ones in the following way: the values from 4.00 to 5.00 correspond to the highest efficiency level; from 3.00 to 3.99 – to the medium level; below 3.00 – the low efficiency level of the tool application. Assessment of efficiency of applying mobile ICT tools to studying each Informatics subject is visualized in Table 1 in the following way: white represents estimates corresponding to the highest efficiency level; pink – the medium efficiency level; dark grey – the low efficiency level.

Fig. 2, 3, 4, 5, 6 shows an example of distributing estimates of efficiency of applying mobile ICT to teaching 1 group of Informatics subjects.

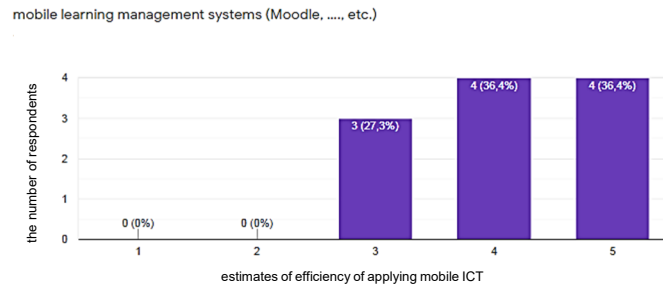


Fig. 2. Distribution of estimates of efficiency of applying Mobile Learning Management Systems

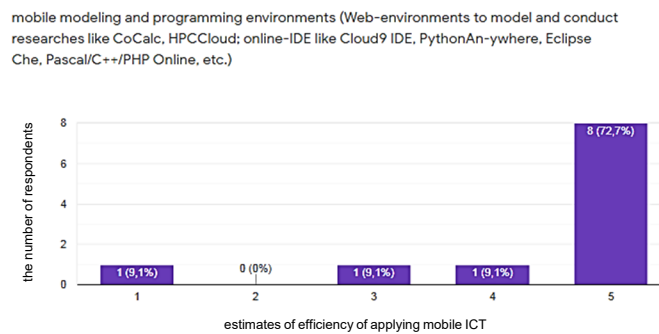


Fig. 3. Distribution of estimates of efficiency of applying Mobile Modeling and Programming Environments

mobile database management systems (InterBase, SQL Anywhere, Microsoft SQL Server, IBM DB2 Everyplace, Oracle Database Lite, SQLite, etc.)

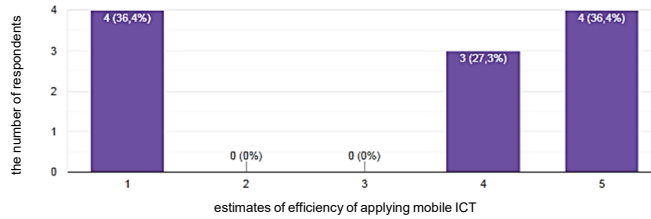


Fig. 4. Distribution of estimates of efficiency of applying Mobile Database Management Systems

mobile multimedia authoring tools (audio- and video-services like YouTube, Vimeo, etc.; online presentation editors like Prezi, Google Slides, etc.; animation editors like VideoScribe, etc.; graphical editors and augmented reality tools like Paint 3D, SketchUp, etc.)

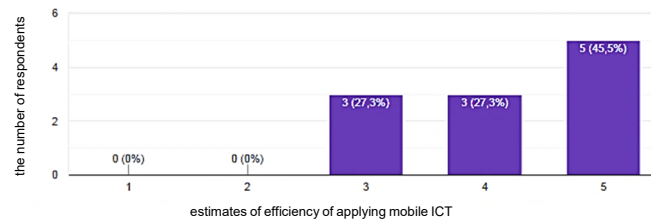


Fig. 5. Distribution of estimates of efficiency of applying Mobile Multimedia Authoring Tools

mobile audience response systems (Google Forms, EasyTestMaker, Online TestCreator, etc.)

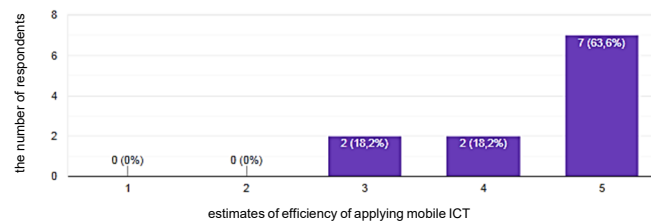


Fig. 6. Distribution of estimates of efficiency of applying Mobile Audience Response systems

To determine the average estimate of efficiency for the subject group, the value $\langle A \rangle$ is calculated:

$$\langle A \rangle = \frac{1}{n} \sum_{i=1}^n A_i, \quad (1)$$

where $\langle A \rangle$ is the average estimate of efficiency for each of the 19 subject groups.

To determine the average estimate of efficiency for each mobile ICT tool, the value $\langle B \rangle$ is calculated:

$$\langle B \rangle = \frac{1}{n} \sum_{i=1}^n B_i, \quad (2)$$

where $\langle B \rangle$ is the average estimate of efficiency for each of the five mobile ICT.

Analysis of the expert assessment results has revealed that:

- the most efficient mobile ICT tools for teaching Informatics subjects are mobile audience response systems and mobile learning management systems as for all the subjects they are noted for the highest efficiency level and can be considered universal mobile ICT tools of teaching Informatics subjects;
- mobile multimedia authoring tools have a high efficiency level of application for all Informatics subjects except for Low-Level and Systems Programming (for both subjects, the efficiency estimates equals 3.91) that also enables considering them universal;
- mobile modeling and programming environments have a high efficiency level for teaching the subject block of theoretical principles of Informatics and most subjects of the algorithmization and programming block (except for Visual Programming and Low-Level and Systems Programming);
- mobile database management systems have a high efficiency level of application (4.82) only for Database Programming.

Mobile ICT tools with a high efficiency level for a certain Informatics subject will be called leading mobile ICT tools for a given subject and those with a medium efficiency level – auxiliary mobile ICT tools for teaching a given subject.

Analysis of the averaged efficiency estimates for different classes of mobile ICT learning tools confirms the first and the second conclusions on universality of mobile audience response systems, mobile learning management systems and mobile multimedia authoring systems as their average efficiency estimates equal 4.33, 4.15 and 4.23. Mobile modelling and programming tools and mobile database management systems have a medium efficiency level (3.70 and 3.21 respectively).

Besides, the Informatics subjects with the highest efficiency level of applying mobile ICT tools were singled out, namely: Database Programming (4.31), Basics of Algorithmization and Elements of Programming (4.15), Web Programming (4.15), Software Design Technologies (4.13), High-Level Programming Language (4.11), Discrete Programming, Operations Research, Computer Logic, Theory of Automatic Control (4.07 for them all).

4 Conclusions

1. According to the expert assessment results for each content block of Informatics subjects, there are determined leading and auxiliary mobile ICT learning tools. It is revealed that mobile audience response systems and mobile learning management systems are universal tools for teaching Informatics subjects; mobile multimedia

authoring tools have a high efficiency level for all Informatics subjects, except for Low-Level and System Programming and System Software, this fact also enabling us to consider them universal. Mobile modelling and programming environments are leading tools for teaching Theoretical Basics of Informatics and Basics of Algorithmization and Programming (except for Visual Programming and Low-level and System Programming); mobile database management systems are leading mobile tools only for Database Programming.

2. The cooperative use of mobile multimedia authoring tools and mobile audience response systems to support the professional training of future professionals in engineering pedagogy is the driver for changing the Informatics' learning environment from virtual based to augmented.

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Organizational and pedagogical conditions of ICT health-saving usage at school: guidelines for teachers

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Abstract. The article describes the organizational and pedagogical conditions of information and communication technology (ICT) health-saving usage at middle school. The model of realization of named conditions and the model of cooperation of participants of the educational process within health-saving use of ICT was developed. The examples and hints of how to implement the organizational and pedagogical conditions of ICT health-saving usage are given.

An empirical study showed that in the experimental group that studied under the authors' conditions, the number of students demonstrated high results in three directions (attention stability and mental capacity, healthy vestibular-motor reactions, positive psycho-emotional state) that are much ahead of those obtained in the control group. Consequently, the obtained data showed the effectiveness of the conditions developed by the authors. It is emphasized that the named conditions can be realized only through the concentration of efforts and concerted interaction of all parties of the educational process.

Keywords: Information and Communication Technology (ICT), Health-Saving Use of ICT, School Teacher, School Students, Organizational and Pedagogical Conditions.

1 Introduction

At the present stage of the society development, information and communication technologies (ICT) have become an integral part of human life, integrating into all spheres of social activity, leading to the development of the information society, updating and intensifying the processes of data exchange, professional and interpersonal communication, acquiring knowledge, etc.

The educational field, including general secondary education, has undergone significant changes. Informatization of general educational institutions leads to the search for new effective teaching approaches and methods, revision of educational standards, the content of disciplines and curricula, the introduction of advanced technologies, etc. The use of ICT in educational activities helps to diversify the range of didactic tools, increase the opportunities for improvement of the pedagogical process.

Along with this, it is widely known that students' work with ICT is associated with increased mental, nervous, emotional and visual load (M. Ciccarelli, S. Dockrell, A. Dymova, A. Hainsworth, H. Hun, K. Jacobs, V. Lamanaskas, I. Muhametzyanov, N. Polka, T. Tran, P. White, H.Ch. Woo, et al.).

Thus, training sessions in computer class cause long-term preservation of the working posture forced and the corresponding static load, strain of visual receptors, etc. Analysis of studies of the impact of these remedies on the health of students, obtained by experts in various industries (M. Ciccarelli, S. Dockrell, A. Hainsworth, P. Hakala, T. Tran, I. Williams, R. Zlamanski, et al.) allows us to assert that often the negative consequences are due to human factors and are related to non-compliance with basic ergonomic, psychological and sanitary requirements. This is especially true for middle school students (teenagers) who are experiencing complex processes of physiological and socio-psychological formation (D. Elkonin, E. Erikson, E. Hazen, V. Kutishenko, L. E. Levine, R. A. Sanders, L. Vyhotskyi, et al.).

Adolescent health statistics look disappointing. Thus, according to the Ministry of Health of Ukraine, in the last years, the health of teenage children remains unsatisfactory with a negative tendency to worsen [3]. Since 2010, the number of teenagers aged 15–17 who are not engaged in physical activity at all has been increasing. The average time spent by them at a computer on the Internet is up to 2 hours on weekdays and up to 6 hours a day on weekends [2]. This is due to various socio-economic factors: social life, low level of medical knowledge and valeological culture, low level of safe living skills and health-saving competence, indifferent attitude of adults, etc.

According to the Concept of the New Ukrainian School [7], the educational establishment should create the optimal conditions for maintaining and promoting the health of all participants in the educational process. Therefore, it is important for teachers working with adolescents to be competent in creating the right learning conditions and designing a health-friendly educational environment.

2 The presentation of main results

2.1 Organizational and pedagogical conditions of ICT health-saving usage at middle school

An important basis for the health-saving use of ICT in the educational process is compliance with appropriate organizational and pedagogical conditions.

As a rule, the elements of organizational and pedagogical conditions include material and technical base, forms, methods, aids, technologies of the pedagogical activity, conceptual theories and principles of the organization of training, the professionalism of educators, artificially created and objectively formed pedagogical situations, etc.

We consider organizational and pedagogical conditions as a component of the pedagogical system, a set of specially created conditions, which are the result of purposeful concerted interaction of the participants of the educational process, which allows achieving the set goals, namely – ICT health-saving usage in the educational process.

We have identified a range of organizational and pedagogical conditions for the health-saving use of ICT at school: 1) formation of a health-saving component of students' digital competence, 2) interdisciplinary integration of the health-saving content of different subjects, 3) compliance with the sanitary and hygiene requirements for the arrangement and equipment of computer training rooms, 4) ensuring the adaptability of the student's workplace, 5) quality of hardware and software, 6) pedagogically balanced selection of ICT tools, 7) changing different activities in the lesson (including physical relaxation after working with ICT), 8) creating a psychologically favorable atmosphere in the educational process, 9) coordinated interaction of all subjects of the educational process.

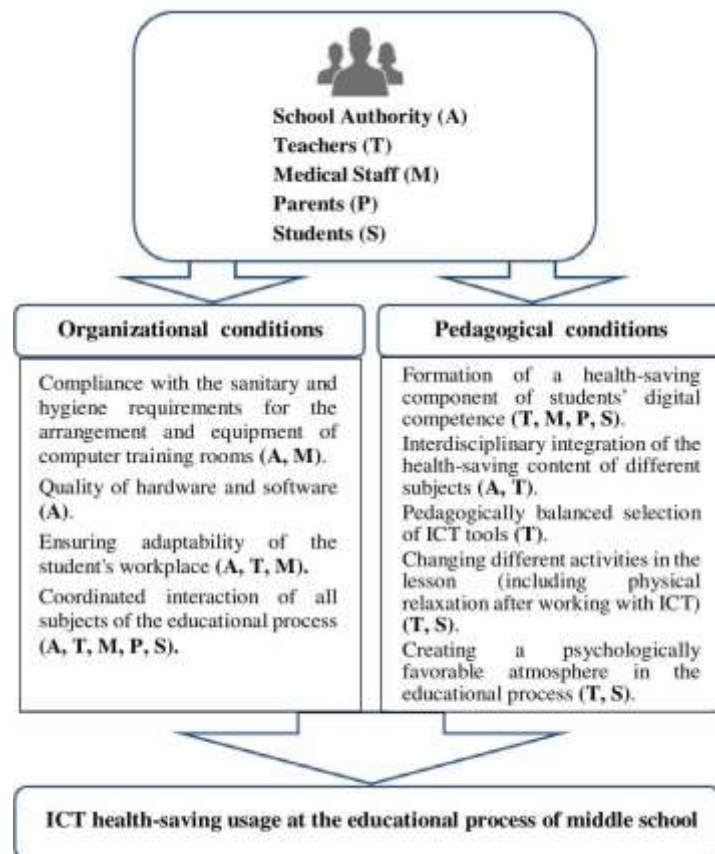


Fig. 1. Model of realization of organizational and pedagogical conditions of health-saving use of ICT at the school level

In figure 1 the model of realization of named conditions is presented, as well as it is defined those who should be responsible for their implementation: school authority, educators, medical workers, parents, students.

Let us consider these conditions and discuss in more detail those ones which can be implemented with the participation of teachers.

Formation of a health-saving component of students' digital competence. As a result of our research, we conclude that knowledge and skills and of health-saving use of ICT should be considered within the digital competence as one of its components, because:

1. Effective work with ICT is impossible without the knowledge and observance of norms and requirements for their safe, health-saving use.
2. The formation of competences for the safe use of ICT must precede their direct use in the educational process.
3. The development of competence in health-saving use of ICT should be conducted concurrently with the use of ICT throughout the study period, and mainly during the study of computer sciences.

Formation of a health-saving component of students' digital competence involves the formation of a set of relevant knowledge, skills, attitudes, beliefs, motivations aimed at maintaining physical and mental well-being and health. We believe that this is the basis for ensuring the safe use of ICT. The author's methodology for the development of this competence is presented in the article [6]. Mainly the realization of this task is assigned to teachers.

Interdisciplinary integration of the health-saving content of different subjects.

The formation of the health-saving component of students' digital competence, their ability to use ICT safely, should occur systematically and consistently, not only during the study of computer science, but also other educational subjects of the school cycle: biology, informatics, physics, physical culture, etc., as well as in the form of messages and discussions during electives, thematic classes, etc. The table provides an example of how teachers in different subjects can introduce health-saving content into the learning process.

Table 1. Table 1. Hints for introducing health-saving content in teaching school subjects

Subject	Integration of health-saving content concerning for the use of ICT
Native/foreign language and literature, foreign language	Reading texts, writing works, translations, essays, discussing health-saving issues (5-9 classes ¹).
Natural science	Formation of concepts about systems of inanimate nature, incl. general concepts of information systems and objects; developing skills to assess the level of environmental safety as a sphere of life (5 class ²).

* According to the curriculum of the middle school (Ukraine)

Biology	The study of the characteristics of the adolescent organism, its vulnerable aspects, the potential negative effects of the environment and the possibilities of their avoidance. Formation of the idea of the essence, value, and interconnectedness of all systems of the human body (6-9 classes*).
Physics	Formation of concepts about electromagnetic waves, X-ray, ultraviolet, infrared radiation, ionization of air, the nature of their occurrence and impact on humans (7-9 classes*).
Health Basics	Formation of knowledge about health and safety of life, healthy lifestyle, ability to use the knowledge gained in practice. Acquisition of safe behaviors that enhance the physical, social, spiritual and mental health components. Formation of value attitude to one's life and health, positive attitude to the rules of a healthy and safe lifestyle and observance of them (5-9 classes*).
Computer Science	Learn the basics of using ICT safely. Formation of concepts about computer architecture, software and hardware, rules for their safe use. Formation of knowledge about the ergonomics of the workplace, sanitary and hygienic norms of work with PCs, their observance during the lessons (5-9 classes*).
Extra-curricular activities	Conducting thematic sessions on the problem of the safe use of ICT. Discussion of computer addiction, unauthorized use of computer equipment, potential threats and consequences for adolescents, options for avoiding them (5-9 classes*).

Compliance with the sanitary and hygiene requirements for the arrangement and equipment of computer training rooms. Compliance with this condition minimizes the potential negative impact of the remedies on the body of the younger generation, helps to avoid overwork and maintain a stable performance throughout the lesson. Among the main ones, there are the requirements for training rooms, lighting, air-thermal regime, equipment and organization of workplaces, time regulations for the work of students with ICT, etc. The main responsibility for their compliance rests with the heads of educational institutions and teachers. There is currently no standard in Ukraine to regulate the use of modern gadgets at school for different age groups. Therefore, its development remains on the agenda.

Ensuring adaptability of the student's workplace. The adaptive workplace of the student should match his/her age, height, posture, and its components (desk, chair, arm-rests, monitor placement, keyboards, etc.) should be comfortable and ergonomic, without hampering movements or creating unnecessary load on the bone, muscular system, vision, etc. Besides, adaptability implies that individual components of the workplace can be adjusted (adapted) depending on the individual characteristics and needs of the student (e.g., height, vision, etc.). The teacher needs to make sure that before the start of the class, the students pre-configure (adapt) the workplace for the comfortable use of ICT.

Quality of hardware and software. In international standards ISO 9000:2000 quality is characterized as a set of characteristics of the object that meet the requirements of the consumer. In our case, the quality of ICT is determined by its safety for the consumer's health (lower radiation, better image quality, ergonomics, etc.). Obviously, a modern LCD will have less of a negative impact on the user than a display with a ray tube. Therefore, we consider such ICT better in terms of health-saving. The basic guidelines that will allow you to choose better products are discussed in the guide [4, pp.

148-150].

Pedagogically balanced selection of ICT tools. The effectiveness of the learning environment depends not only on the quantity and quality of the means used in it but also on how pedagogically balanced they are applied. We believe that the use of ICT in a lesson is well-considered and pedagogically appropriate if the complete solution of specific didactic tasks cannot be fully implemented or complicated without their use. For example, to clarify phenomena, concepts, theories, etc. that cannot be observed and explored in the ordinary context (space objects, micro-objects, historical events, etc.).

When planning a lesson, the teacher should carefully consider the appropriateness of using ICT in the study of a topic in general and in a specific part of the lesson, in particular, to balance the potential benefits to the educational process and the health risks to students. New technologies do not have to completely replace and displace traditional techniques but instead, complement them harmoniously. By optimizing pedagogically the frequency and duration of work with ICT, the health-saving effect of their use can be enhanced.

Changing different activities in the lesson (including physical relaxation after working with ICT). Maintaining a high level of students' working capacity is possible at the expense of rational organization of the lesson, change of different types of activity, following the correct posture during each type of activity, holding of physical short breaks.

Physical short breaks should be an integral part of the lesson. The generally accepted norm is to conduct a short physical warm-up lasting 1-2 minutes every 20-35 minutes during a lesson, whether or not ICT was used. After working with ICT, one needs to include a functional warm-up for the eyes, wrist, back and neck in the complexes of dynamic pauses. Dynamic pauses can take place either under the guidance of the teacher or by the student on their own (e.g. at home). In this case, special timer programs will be useful to set the appropriate time range for the break reminder (e.g. «SYE Timer», «Opti-Ergo EyeSaver», «Eyes Saver», «Time On», «Tadam», etc.).

Creating a psychologically favorable atmosphere in the educational process. Stress, chronic emotional tension of both students and teachers, are negative factors that are destructive to the well-being and psychophysical state of the younger generation. The ability of the teacher to prevent and neutralize unwanted emotional reactions, constructively resolve conflicts in the student group, attests to his/her ability to manage the educational process, creating a healthy atmosphere in the classroom.

Coordinated interaction of all subjects of the educational process. Provision and implementation of the named organizational and pedagogical conditions of health-saving use of ICT are possible only by combining the efforts and coordination of influence and actions of all subjects of the educational process: heads of educational institutions, pedagogical staff, medical staff, parents, students, etc. Mass media, cultural, civic organizations, etc. may play an important role in this process.

Let's take a closer look at the key functions of the main stakeholders of the educational process (figure 2).

The main responsibility for creating the appropriate organizational environment relies on the educational institution authority – head (director) of the school and his/her deputies. Thus, the director oversees the implementation of the relevant rules and regulations, sanitary and ergonomic standards, provides a comprehensive approach to

health care support of the educational process. In part, he/she can also influence the purchase of quality hardware and software tools, ergonomic furniture, climate control and more.

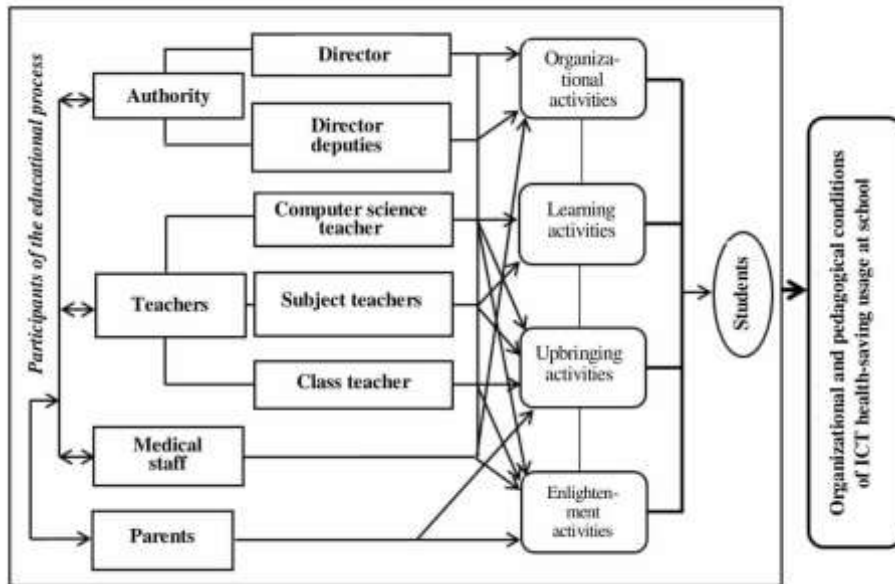


Fig. 2. Model of cooperation of participants of the educational process within health-saving use of ICT

The powers of the deputy director of educational work include the organization of educational activities aimed at forming the health competence of teachers, students, and parents, in the form of thematic evenings, meetings with experts, etc.

The functions of pedagogical staff include improvement of the educational process based on improving the efficiency of health-saving, enlightenment activities. The primary role should be attributed to the computer science teacher, as the chief specialist in the use of ICT, responsible for the equipment of the computer class and compliance with proper sanitary and hygiene requirements. The direct work of students with ICT should be preceded by training on their health-saving use and introductory safety training, which should be the responsibility of the computer science teacher.

The formation of a health-saving component of students' digital competence, as one of the most important organizational conditions for the health-saving use of ICT, should occur systematically and consistently, not only when studying computer science, but also in other subjects. The main role in this belongs to teachers.

An important participant in the educational process is the class teacher. The main functions and forms of his/her influence include the following: holding thematic sessions and parental meetings on the problem of the safe use of ICT; discussion of com-

puter addiction, unauthorized use of computer equipment, its potential threats and consequences for the adolescent organism, and how to avoid them; preparation together with students of relevant projects (thematic wallpapers, weeklies, etc.).

Healthcare professionals should play a direct role in creating the school's health care environment in general and in the health care organization of the educational process in particular. Their main functions include keeping records of students' health status, updating information on potential negative consequences of the use of ICT, communicating this information to other subjects of the educational process, monitoring the organization and compliance with sanitary and ergonomic conditions, checking and assessing lessons from a health-saving point of view, etc.

Students need to exercise self-regulation, self-control, and self-reflection in the context of health-saving, both during school and at home; to develop a health-saving component of digital competency, enhancing knowledge and skills on health-saving use of ICT.

Parents are important participants in the educational process. Their full inclusion requires participation in educational activities organized at school, self-education, conversations with the class teacher, other teachers, and medical staff, educational work with children on the health-saving use of ICT, organization of a health-saving home and educational environment for children at home.

Thus, we have identified and characterized the main organizational and pedagogical conditions of health-saving use of ICT in the educational process. All named conditions can be realized only through concentration of efforts and coordinated interaction of all subjects of the educational process. And the main role belongs to the teacher.

2.2 Implementation of organizational and pedagogical conditions of ICT health-saving usage at middle school

Each school can determine its ways of implementing named organizational and pedagogical conditions, depending on the tasks, available resources, staff, etc. We propose some hints and examples based on our experience (table 2).

Table 2. Examples of how to implement the organizational and pedagogical conditions of ICT health-saving usage

№	Organizational and pedagogical conditions	Measures conducted
1	Formation of a health-saving component of students' digital competence.	Teaching students according to the author's methodology (within a specialized training course, elective, etc.) [4, 6].
2	Interdisciplinary integration of the health-saving content of different subjects.	Conducting a thematic seminar-presentation for subject teachers (to explain the essence of named condition). Introductory training for teachers under the author's manual [4].
3	Compliance with the sanitary and hygiene requirements for the arrangement and equipment of computer training rooms.	Checking the compliance of the computer class equipment with the current hygiene standards. For example, checking if the peripherals (printer, scanner, router) are located far enough from the students (3 m and more), etc.

4	Ensuring adaptability of the student's workplace.	Interviewing students about the adaptability of their workplaces (orally or in writing). For example, we use a questionnaire developed by the British company "Borough Council of King's Lynn & West Norfolk" [8], which we adapted to our study.
5	Quality of hardware and software.	Checking the computer class if it is equipped with state-of-the-art equipment that minimizes the negative impact on users' health (e.g. LCDs). Updating the equipment as needed (via budget, sponsorship, etc.).
6	Pedagogically balanced selection of ICT tools.	Including ICT in the lesson just in a case if the complete solution of specific didactic tasks cannot be fully implemented without their use. Using ICT within acceptable time limits for the selected age group of students of 5-9 classes (20-25 minutes).
7	Changing different activities in the lesson (including physical relaxation after working with ICT).	Performing relaxation exercises after the completion of working with ICT, including physical relaxation.
8	Creating a psychologically favorable atmosphere in the educational process.	Establishment of cooperation with subjects of the educational process, in particular parents. Application of democratic teaching style, use of interactive methods, game techniques. This facilitates the establishment of a psychologically favorable atmosphere, the inclusion of each student in educational work.
9	Coordinated interaction of all subjects of the educational process.	We have taken several steps: - A thematic seminar-presentation for subject teachers was held. The authors' manual [4] was provided. - A series of training sessions for the students by the authors' methodology, aimed at forming their health-saving component of digital competence. Educational guidelines [4, 5] are provided. - Parents were interviewed to draw their attention to the problem. A recommendation booklet "Using ICT without harm to health".

2.3 Research of efficiency of organizational and pedagogical conditions of ICT health-saving usage

For verification the efficiency of organizational and pedagogical conditions named above, a range of diagnostic methods were used:

- to determine the level of attention stability and mental capacity – psychological methodology of E. Kraepelin in the modification of R. Schulte;
- to examine vestibular-motor reactions – K. Trynus method;
- to determine the psycho-emotional state of students – authors' questioner.

We consider all mentioned (attention stability and mental capacity, healthy vestibular-motor reactions, positive psycho-emotional state) to be the important elements of the effective and health-saving educational process.

The diagnostic involved the formation of control and experimental group of students (CG and EG appropriately), which were formed as follows:

- CG included 143 students of 7-9 classes. These students worked with ICT on computer science lessons in the usual mode. At the beginning and the end of the lesson, diagnostic methods were conducted.
- EG included 137 students of 7-9 classes. For these students, the range of measures described in the previous chapter was applied. At the beginning and the end of the lesson, diagnostic methods were conducted as well.

Using the Student's t-test, we obtained the result ($t = 2,78, t > t_{\alpha}$, at the level of significance $\alpha = 0,05$), which was a confirmation of CG and EG coincidence.

We propose to consider the results obtained in more detail.

The results of the determination of students' attention stability and mental capacity. Attention stability and mental capacity are important psychic properties that directly affect the effectiveness and success of the educational process. Because healthy mental processes are an integral part of overall personal health, the task was to analyze the dynamics of students' attentiveness and mental capacity before and after using ICT, namely a computer.

As a diagnostic tool, we chose the psychological methodology of E. Kraepelin in the modification of R. Schulte, allowing studying the level of attention and mental performance when performing a simple monotonous job. This technique made it possible to evaluate the fatigue of the CG and EG students before and after working at the computer.

Almost identical results were recorded at the beginning of the lesson both in CG and EG. Thus, the high level of attention stability and mental capacity was demonstrated by 68% of CG students and 69% of EG, medium level – 16% of CG and 12% of EG, low level – 16% of CG and 19% of EG.

At the end of the lesson, the EG showed the best results: high level – 52% of CG and 66% of EG, medium level – 32% of CG and 30% of EG, low level – 16% of CG and 4% of EG (Figure 3).

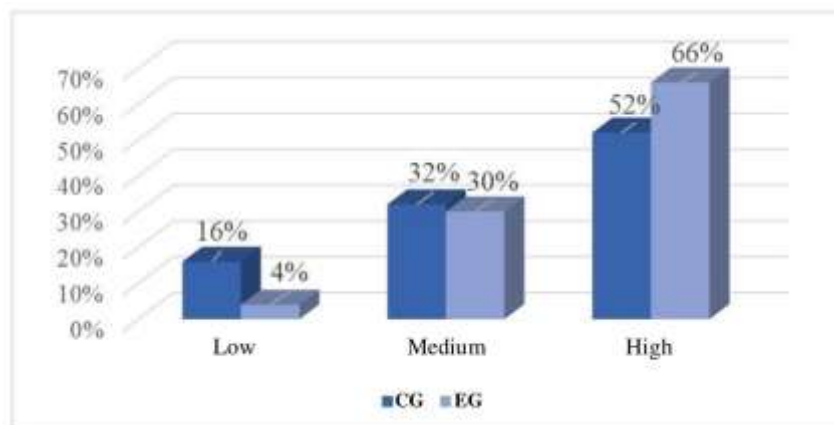


Fig. 3. Level of students' attention stability and mental capacity at the end of the lesson

To test the correctness of the results obtained in the dependent samples, the Fisher test was applied, which showed the validity of the differences between EG and CG, and amounted to 99%.

Thus, students of EG showed higher levels of attention stability and mental capacity at the end ICT computer use than students of CG. Mastering the basic principles of the healthy use of ICT and putting them into practice allows students of EG to stay longer at the high and intermediate levels of mental processes, which are key to effective learning.

The results of examining students' vestibular-motor reactions. As noted by K. Trynus, the vestibular apparatus is the human organ responsible for the perception of linear and angular accelerations, as well as the position of the body in space [1], and it is of great importance for the human mental health.

The range of disorders of the vestibular apparatus functions is quite wide: headache, sleep disorders, darkening of the eyes, dizziness, disorders of movement coordination, memory disorders, irritation, etc. The negative reaction of an organism is possible even after short work with the computer, in case the ergonomic norms and conditions of its use are not observed. In particular, this is manifested in the change of functional state of the vestibular apparatus.

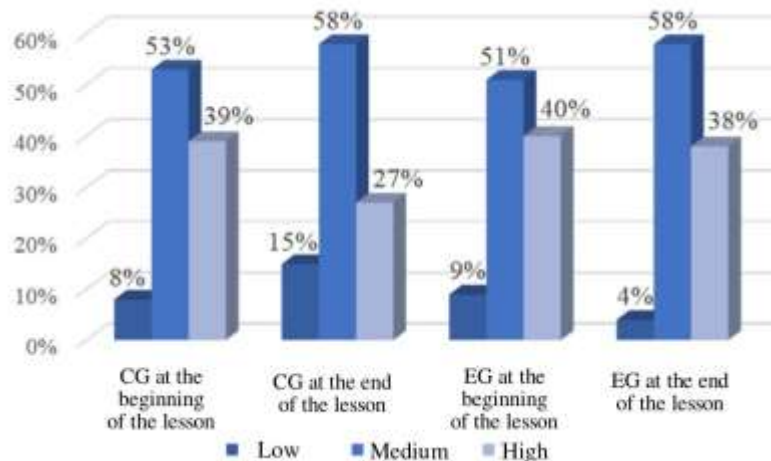


Fig. 3. Dynamics of levels of students' vestibular-motor reactions at the beginning and the end of the lesson

The results obtained (Figure 4) testify to the effectiveness of organizing the educational process of EG students, who worked accordingly to authors' recommendations.

To test the correctness of the results obtained in the dependent samples, the Fisher test was applied, which showed the validity of the differences between EG and CG, and amounted to 99%.

Thus, EG students have higher levels of vestibular-motor reactions at the end of the lesson using ICT than CG students. The results of statistical processing of the data obtained as a result of diagnostics by the method of K. Trynus testified that the health-saving use of ICT in the lesson leads to a longer storage of the level of vestibular-motor reactions of students, which is an integral part of productive learning, the stability of mental processes, efficiency and successful learning in general.

The results of the determination of students' psycho-emotional state. The success of the educational process depends largely on the mental state of the student. The mental state is a set of characteristics of mental activity for a certain period. Mental state includes emotions, attention, anxiety, attitudes, pleasure and dissatisfaction, apathy and inspiration, cheerfulness and fatigue and more. A student's emotional state is an integral part of his/her mental health. Therefore, the establishment of a psychologically favorable atmosphere in the classroom should be organized by the joint efforts of the teaching staff and be aimed at ensuring trust, kindness, free expression of students' opinions, lack of excessive pressure and authoritarianism, tolerance, equal opportunities for self-realization, mutual support, security, etc.

At the lesson when working with ICT, the students' mental and physical sphere indicates the influence of factors of both objective (electric field voltage, electromagnetic radiation, static electricity, increasing the level of ionization of the air, etc.) and subjective nature (overload (static and dynamic), vision strain, mental stress, and fatigue, etc.).

In addition to special methods for determining the psychophysiological state of a person, one way is to analyze the data obtained through self-assessment of the person's state, feelings, emotions. The main evidence of maintaining the students' satisfactory condition is maintaining their interest and enjoyment of the lesson, emotional upliftment, well-being. In this concern, we developed a special questioner.

The answers to the following questions were distributed as follows: at the end of the lesson, most EG students feel their selves interested (82%), feel the pleasure of the lesson (65%) and emotional uplift (57%). CG students, appropriately, demonstrate lower rates: feel interested 72%, feel the pleasure of the lesson 57% and emotional uplift – 43%.

The proportion of students with good feelings at the end of the lesson was 93% in EG and 87% in CG.

Most students stated that they felt light fatigue (41 % in CG and 26% in EG) and physical discomfort (21% in CG and just 6% in EG).

Although the rates of deep fatigue are low in both groups, they are still slightly higher in CG – 3%, whereas in EG only 1%.

In general, the quantitative indicators of the psycho-emotional state of the students obtained via the authors' questionnaire proved the results in EG to be higher than in CG.

Conclusions

Thus, in modern conditions of ICT widespread it is necessary to minimize potential risks connected with their implementation, to assure their health-saving usage among

the young generation. The important task for educators who work with middle school students (adolescents) is to create a safe and health-friendly educational environment.

The organizational and pedagogical conditions for the health-saving use of ICT that we have developed can be of help: 1) formation of a health-saving component of students' digital competence, 2) interdisciplinary integration of the health-saving content of different subjects, 3) compliance with the sanitary and hygiene requirements for the arrangement and equipment of computer training rooms, 4) ensuring the adaptability of the student's workplace, 5) quality of hardware and software, 6) pedagogically balanced selection of ICT tools, 7) changing different activities in the lesson (including physical relaxation after working with ICT), 8) creating a psychologically favorable atmosphere in the educational process, 9) coordinated interaction of all subjects of the educational process.

The proposed models of realization of named conditions of health-saving use of ICT, which include the main responsible parties (school director and his/her deputies, pedagogical and medical staff, students, parents) might be recommended for the implementation at the school level. The main responsible functions belong to the school authority and the main implementation activities belong to teachers.

Still, the named conditions can be realized only through the concentration of efforts and concerted interaction of all parties of the educational process.

The efficiency of organizational and pedagogical conditions of health-saving use of ICT was proved via a range of diagnostic methods, namely concentrated at measuring levels of students' attention stability and mental capacity, vestibular-motor reactions, psycho-emotional state.

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Providing the Fundamentalisation of Operations Research Learning Using MAXIMA System

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Abstract. In the article, the problems of using the systems of computer mathematics (SCM) as a tool to provide the fundamental component of operations research learning and students research activities support are considered. The role of SCM in the process of bachelors of informatics training and special aspects of pedagogical applications of these systems in the “Operations research” study is defined. The analysis of the basic concepts of the fundamentalisation of education and in particular the basic concepts of the fundamentalisation of informatics disciplines learning is summarized. The attempt to distinguish explicitly and specify the fundamental concepts in the content of “Operation research” learning is made. The method of “Operation research” study using Maxima system as a tool to support the basic concepts learning and an investigation is approved. The results of the pedagogical experiment on MAXIMA application to support the fundamental component of learning in the course of “Operation research” study and the analysis of its results are reported.

Keywords: “Operations research”, MAXIMA, learning tools, fundamentalisation of learning, informatics disciplines, learning environment, educational university.

1 Introduction

1.1 Research objectives

In course of information society formation as scientific and technological progress is currently enhancing, there is a challenge for an educational system to provide training of specialists for their immediate inclusion in the technological processes at the production level. After all, it is impossible to predict accurately at the time of enrollment at the university the state of the art of technological achievements that could be reached at the moment of graduation [14].

The way out of this critical situation in the education system is in the fundamentalization of education, which is due to the orientation of the education system to create holistic, generalized knowledge that would be the core of all the knowledge acquired

by the student, which would unite the knowledge gained during the training process into a single system [11].

According to V. G. Kinelev, the purpose of fundamental education is to create favourable conditions for the development of flexible and multifaceted scientific thinking, various ways of perceiving reality, the formation of an internal need for self-realization and self-education throughout life [4].

Over time, the rapidly growing amount of diverse information leads to "the need for their adequate structuring and reflection in the disciplines. Mathematics and informatics disciplines play an important role in the process of mastering some of the most basic knowledge that is the basis for the formation of general and professional culture, rapid adaptation to new professions, specialities and specializations " [3].

The aim of the article is the justification of Maxima system use of in the process of "Operations research" learning in a pedagogical university as a toll for fundamentalisation of learning and providing investigative approach through the analysis of the basic concepts in the course of study.

1.2 Problem statement

The role of fundamental knowledge in modern scientific studies is mentioned in the works of many authors regarding the foundations of classical science. In particular, B.G. Kuznetsov notes that the style of physical thinking radically changed in the twentieth century. In particular, he mentions the loss of uniqueness, the erosion of the content of classical physical concepts in their relativistic interpretation [5]. "According to many scientists, in our time it is impossible to say where physics ends and technology begins, where mathematics ends and physics begins" [14], notes L. S. Khizhnyakova. This has a significant impact on the development of teaching methods in many disciplines.

In many studies, the fundamentalisation of education is associated with equal access to education. It is also considered as a "fundamentally-knowledgeable" frame of personality development, provides systematic knowledge, holistic perception of the world and the person in it, the creation of a basis for professional culture and mastery [10], [12], [12].

Nowadays it becomes necessary to form not only specific but also generalized knowledge and skills. Such knowledge and skills, formed in the process of a certain discipline study, are then available for the use in the course of the other disciplines study or for other professional activities [1], [2], [9]. The fundamentalisation of education is facilitated by the consideration and use of interdisciplinary relations, the research work of teachers and students at the intersection of basic and applied sciences [12].

1.3 The Research Methods

In the course of the study, the scientific and methodological foundations of using the Maxima system are substantiated and analyzed for the unchallenged fundamentalisation of the training of computer science disciplines for computer specialist. The study is based on the methods of theoretical analysis, generalization and systematization of

scientific facts about the pedagogical processes and phenomena, methods of system analysis and modelling, pedagogical observations and generalization of pedagogical experience, as well as the results of the pedagogical experiment. The study was carried out in the framework of the implementation of the planned research undertaken in the Institute of Information Technologies and Learning Tools of NAES of Ukraine and the Department of Informatics and Computing Mathematics of the Drohobych Ivan Franko State Pedagogical University.

Such interdisciplinary methods and procedures are used in informatics as analysis and synthesis, induction and deduction, visualization and formalization, algorithmization and programming, informative-logical, mathematical and computer modelling, program management, expert evaluation, identification and others. It is necessary to acquire them in complex, otherwise, there is not a sufficient level of mastering the material of informatics disciplines.

2 The Research Results

The combination of education and science is a condition for the modernization of the education system, the main factor for further development should be provided by the fundamental education, the intensification of scientific research in higher educational institutions, research institutions [13].

S. O. Semerikov, determining the fundamentalisation of education by the totality of interrelated functions (methodological, vocational, developmental, prognostic, integrative), determines the appropriate ways to provide the educational process with fundamental components [12]:

- saturation of the content of higher education with systemic theoretical knowledge, fundamental theories, concepts, ideas;
- the dominance of research methods of teaching, creative activity, integration of ideas and methods of science, teaching and scientific creativity;
- self-development of a student as a subject of mobile educational, professional and research activities.

In the process of computer science specialists training in fundamental disciplines, it is necessary to attribute primarily philosophical, informatics and natural-mathematical, as well as professional and practical training disciplines. Along with the relevant knowledge, the opportunity to study professionally oriented disciplines should be provided, so the fundamental knowledge that is the most basic and stable in time provide the possibility of further professional growth of a specialist [12], [13].

The essential feature of the fundamental disciplines is that in the process of study the mechanisms of cognition and the basics of understanding the processes and phenomena of the world are formed. The pragmatic necessity of applying a certain mathematical apparatus or understanding the essence of a certain physical effect when performing a professional task requires additional study of mathematical and natural disciplines.

Fundamental learning provides the theoretical foundations of the speciality following the requirements for the level of theoretical training of a teacher of the corresponding profile and is based on the latest achievements of science [6].

According to M. I. Zhaldak, the use of modern ICTs plays an important role in the fundamentalisation of knowledge, a comprehensive and thorough study of the domain, the formation of knowledge necessary for a valid explanation of cause-effect relationships of the processes and phenomena studied. Fundamental knowledge is important for applied research, and the needs of everyday practical activity of people cause and stimulate the corresponding cognitive activity, aimed at the disclosure of laws of a fundamental nature [16].

Higher education in informatics is largely based, as before, on the foundations of an accumulative model of new knowledge, when skills are formed to solve standard professional tasks, act in known situations [10].

We consider the organization of information and educational space at universities as the basis for fundamental teaching of mathematics and computer science, while the task is not the formation of pragmatic, highly specialized knowledge, but methodologically important, invariant knowledge, based on a holistic perception of the world, intellectual development of personality being able to be adapted to rapidly changing socio-economic and other general processes. The fundamentalisation of informatics specialists training is based on the emphasis in the content of instruction on philosophical and mathematical foundations of educational disciplines. The practical implementation of this process in the preparation of future specialists in computer science should be carried out using computer mathematics systems that arise through supporting the teaching of mathematical and computer sciences, by combining the theoretical and applied components of student training, strengthening the professional orientation of their education and the implementation of inter subject communications [12], [15], [16].

By the fundamentalisation of informatics disciplines learning, we understand the selection of the basic concepts, fundamental theoretical principles, concepts, ideas underlying the system-forming knowledge and skills in the field of mathematical and informatics disciplines, the implementation of interdisciplinary communications, providing a competency-based approach to improve the level of training students, their full-fledged activities in the information society [15].

An analysis of the basic concepts of the fundamentalisation of education is summarized in Table 1.

In the process of teaching first-year students of speciality 014 Secondary Education (Informatics), Ivan Franko Drogobych State Pedagogical University revealed their conscious orientation for work in the field of computer science. Most of them feel confident when working with popular software environments and quickly perform typical operations. But the need to deviate from the usual technological schemes causes difficulties. The experience of introduction of the systems of computer mathematics (in particular, MAXIMA) into the learning process obtained during the educational experiment that had been conducted in Ivan Franko Drogobych State Pedagogical University in 2016 was disseminated into the learning process of the several educational institutions of Ukraine (Ternopil Volodymyr Hnatiuk National Pedagogical University, Kryvyi Rig National University, Kherson State University and others) [15].

Table 1. Analysis to understand fundamental

Fundamental Fundamental knowledge	large, strong, stable, deep, basic, main (Ozhegov SI) stable and universal general theoretical knowledge, the content of which is noted by generalization, structuredness, in which the internal-no and external connections of various subject areas are revealed, based on which the person's ability is formed to learn new knowledge, to navigate problems (a tool to achieve scientific competencies) (Laptiev V.V.) [6].
Fundamental preparation	strengthened interconnections of theoretical and practical training of a specialist for professional activity, aimed at the formation of a holistic scientific picture of the world, at the individual and professional development of a student, together provide a high level of education (S. Semerikov) [1210].
Fundamentalization of education	a qualitative change in higher education based on the principle of fundamentality, the introduction of theories of a high degree of generalization, with increased information capacity and universal applicability into the educational process (A. Rostovtseva).
Fundamentalization of informatics education	improving the quality of the fundamental preparation of the student, his system-forming and invariant knowledge and skills in the field of computer science, makes it possible to form the qualities of thinking necessary for full-fledged activity in the information society, for the dynamic adaptation of a person to this society, for the formation of the internal need for continuous self-development and self-education, accounting for corresponding changes in the content of academic disciplines and the methodology for the implementation of the educational process (S. Semerikov) [12].
Fundamentalization of informatics training	the selection in the content of the discipline of basic concepts, fundamental theoretical principles, concepts, ideas underlying system-forming knowledge and skills in the field of mathematical and informatics disciplines, the implementation of intersubject communications, providing a competency-based approach to improve the students' level of training, their full-fledged activity in the information society (Shyshkina M.P., Kohut U.P.) [14].

The learner begin to iterate through the available actions to obtain the desired result. The reason for this is the lack of knowledge of those fundamental theoretical and technical principles on which these environments are built. And as a result, the system construction of a new algorithm is practically impossible.

There is a shift in the content of knowledge to the technological side. This is the fact that in real information processes it is objectively difficult to distinguish explicitly and specific fundamental components. The training of mathematical and computer science disciplines as fundamental can be carried out as follows:

- for any level of education, a system of fundamental theoretical principles, concepts, methods and means is being developed, which are studied in this discipline and successfully assimilated. According to such a system, the boundaries of fundamental knowledge for a chosen level are determined;
- the system of each level is used as the basis for the system of the next level and is supplemented by new components and theoretical justifications of previous components;
- the study of each theoretical component is necessarily accompanied by its practical use in the most accessible form. In this case, the student will understand not only the content of the component but the fact that knowledge of the theoretical foundations of computer science is very important for solving practical problems will be obvious. It is very important to show the existence and ways of using the fundamental components of knowledge in modern computer programs and technologies. In this case, the material will be better absorbed.

In mathematical and computer science disciplines three components must be presented in unity: scientific, technical and technological. But they are implemented differently depending on the level and goals of training. At each level, a place must be found for fundamental knowledge.

The role of the fundamental component is often underestimated. In pedagogical practice, training will be introduced primarily in the technological direction. The methods and techniques used are theoretically substantiated and not analyzed. Students have a poor understanding of the fundamental component of computer science courses compared to mathematics and physics. This is because in real information processes it is objectively difficult to identify, clearly and characterize specific fundamental components. At the same time, fundamental concepts play a key role in the process of fundamentalisation of training, which is also closely related to the basic concepts of related disciplines.

In computer science, such interdisciplinary methods and procedures are used as analysis and synthesis, induction and deduction, visualization and formalization, algorithmization and programming, information-logical, mathematical and computer modeling, program management, expert evaluation, identification and others [12]. They must be mastered comprehensively, otherwise, there will not be a sufficient level of mastery of the material of information disciplines. All this testifies in favour of fundamentality of the content of the training.

At the same time, fundamental concepts play a key role in the process of fundamentalisation of education, which is also closely related to the basic concepts of related disciplines.

For example, the fundamental concepts of an algorithm and operation are closely related to the concept of a function, which can be associated with an operation, the

implementation of which implements this function. Considering the concept of algorithm and operation only from the procedural side, that is, as a prescription characterizing the transformation that must be performed, the process side of this concept remains aside. Then the algorithm acts as a process for solving a specific problem, the result of which is a solution. This concept acquires applied content in solving problems arising in practice. At the same time, excessive bias towards the applied application of the algorithm does not contribute to understanding its relationship with the mathematical foundations of this theory.

Therefore, the selection of the fundamental concepts of informatics disciplines, their awareness and consolidation of the experience of research activities is an integrable component of the organization of training, the creation of intersubject communications, the formation of a holistic system of knowledge and ideas among students about both the theoretical basis and the ways of applying the acquired knowledge in practice.

It is the relationship with the mathematical foundations that are an essential factor in the fundamentalisation of the teaching of information disciplines. In particular, a possible reason for misunderstanding in many cases is that it is not possible in the right sense to consider the relationship between the various aspects of solving the problem - constructing an analytical relationship, and based on the mathematical laws governing the description of the phenomenon, the very phenomenon that a computer program implements are obtained. Using a computer program, you can simulate the dynamics of the system or the manifestation of a phenomenon.

In various disciplines consider modelling various phenomena. In this sense, it is advisable to focus further attention on one of the disciplines where it would be possible to demonstrate the advantages of a systematic approach. For this, the discipline "Operations Research" was chosen, which later became the subject of an experimental study.

Operations research is the theory of using scientific quantitative methods to make the best decisions in various fields of human activity. This science gives objective, quantitative recommendations for managing targeted human actions.

The following fundamental concepts arise in the study of operations: an operation, a system, a model, modelling, a systematic approach, a task, an optimality criterion (quality, efficiency), as well as closely related concepts of a method, procedure, function, in general form the fundamental core of learning mathematics - of general and informatics disciplines. Besides, the so-called fundamental algorithms (methods) play an important role in the content of training in the study of operations, which must be mastered when solving a certain set of classical problems: resource allocation problems (transport problem, assignment problem) network planning problem; the task of choosing a route (the travelling salesman problem) problems of game theory.

By the example of teaching this discipline, one can demonstrate the relationship of mathematical methods and the implementation of the corresponding operations and algorithms with the visualization of results, which reflect the relationship of certain objects and their properties. Based on the curriculum of the course "Operations Research" for the specialities 014 Secondary Education (Informatics) of the Drogobych State Pedagogical University, the fundamentalisation of operations research training can be generalized as follows (Fig. 1).

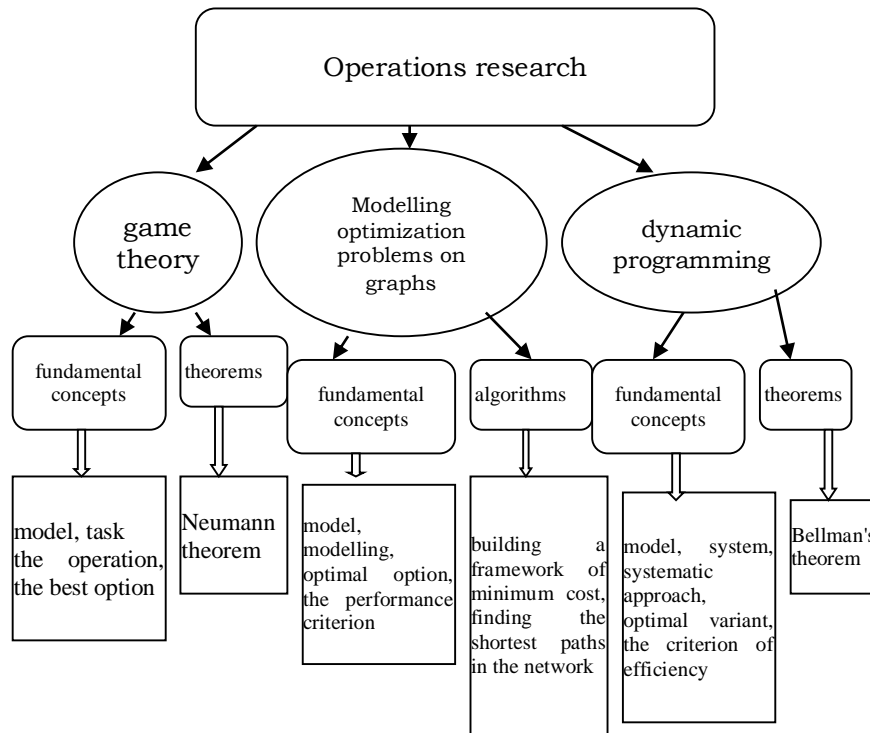


Fig. 1. Fundamental concepts of operations research

To uncover the essence of the problems that arise in the search for the advantages of using ICT in teaching operations research, we need to consider the concept of an educational task.

The training task is aimed at mastering a certain mode of action, while the practical task is to obtain the result contained in the task condition. When solving any of these problems, the subject acquires certain knowledge, but it is the educational tasks that have an exceptional impact on the functioning and development of educational activity [7].

By the example of training in the study of operations, one can demonstrate the relationship of mathematical methods and the implementation of their corresponding operations and algorithms with the visualization of results, which reflect the relationship of certain objects and their properties. This relationship is reflected in the model of the educational task "Operations Research".

The model of using the training task with "Operational Research" (Fig. 2.) reflects the interconnection of fundamental concepts, mathematical method, fundamental algorithm, algorithm and operations that are implemented in the process of solving. This shows the role of fundamental concepts as an integrative component of the training "Operational Research".

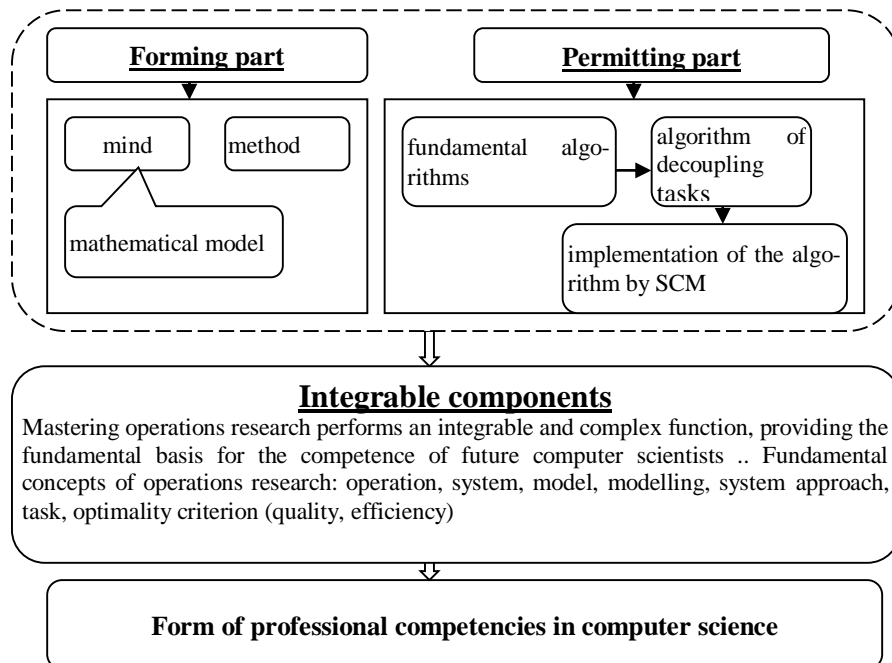


Fig. 2. The model of primary tasks with the previous operation

The use of ICT, in particular SCM as a means of training, is associated with problems of increasing the level of fundamental training of future specialists in computer science:

- combination of theoretical, applied and practical aspects;
- presentations in a systematic form of theoretical information about methods and the main provisions of decision theory, computer mathematics systems and the formation of practical skills for their application to solving real practical problems;
- deepening students' knowledge on issues related to the study of the effectiveness of solving applied problems using computer mathematics systems, analysis and interpretation of the results;
- development of the algorithmic style of students' thinking through the development of algorithms and their software implementation;
- the formation of students' skills of independent work with theoretical material and computer mathematics systems.

Correctly selected tasks of professional orientation for laboratory work enable the teacher to use SCM as a means to ensure inter subject communications between computer science and mathematics. The foundation is laid for the formation of ICT competencies [15].

For each laboratory lesson, individual task options have been developed that are divided into three difficulty levels. The difficulty level of the assignment for completion

is selected by the student. The task of the first level of complexity corresponds to the reproductive level of assimilation of knowledge and is evaluated by a small (up to 5 points) number of points. To solve problems of the second level of complexity, the heuristic nature of the intellectual activity is required; tasks are estimated by the average (up to 15 points) number of points. The third level of complexity includes tasks that require a creative approach. The tasks are formulated in such a way that for their solution it is necessary to have elements of divergent thinking. Divergent thinking is usually inherent in creative individuals, inclined to create new combinations of those elements, others use only the usual way. With the successful completion of tasks of this level, the student deserves the most (up to 20 points) number of points. Thus, differentiation of training is implemented, the student sees the results of his work and can evaluate the objectivity and accuracy of rating points [15].

The most important element of laboratory studies in the course "Operations Research" appropriately selected tasks. Tasks are given to students taking into account the fundamentals of the theory presented at the lecture. As a rule, in a laboratory lesson, the main attention is paid to the formation of specific abilities and skills, based on which the content of students' activity is determined - solving problems, graphic works, clarifying categories and concepts of the studied discipline. When analyzing tasks with students, the teacher should pay special attention to the formation of abilities to comprehend and understand the material on the topic.

Considering the system of individual tasks for laboratory work, as well as tasks for the practical protection of modules, one should analyze the problems and advantages of using such tasks. When preparing tasks, you should carefully approach the determination of the level of difficulty. This can only be helped by the teacher's experience, his ability to identify key points in the training material, and understanding the relationship of the tasks with other disciplines. Also important is the question of the relationship of difficulty levels in one task. For laboratory work, it is more appropriate to set tasks where the fulfilment of tasks of a higher level of complexity is possible provided that the tasks of the previous level of complexity are completed. Otherwise, students often overestimate their capabilities, take on complex tasks immediately, cannot complete them, and they don't have enough time to complete simple tasks. Thus, they do not gain those rating points that they could gain by correctly assessing their capabilities. It is advisable to use tasks of different difficulty levels when conducting modular controls and exam tickets, where you need to cover all the training material.

Each laboratory work is accompanied by a list of questions for self-examination and several tasks to perform during students' independent work. The main task is to form practical skills for future specialists in formalizing tasks and solving them using SCM tools.

On the advantages of a system of multi-level individual tasks, the accuracy and objectivity of the assessment come to the fore here. The classical four-point student competency assessment system, despite its usual simplicity, had some drawbacks regarding the objectivity of assessment. A 100-point rating system gives greater accuracy in the assessment, but here the problem arises of ensuring this accuracy - what maximum error can a teacher make when setting rating points. Differentiation of the complexity of

tasks, and accordingly the number of points for their implementation, allows to some extent to ensure acceptable accuracy and objectivity of the assessment.

Differentiation of the rating of students is also carried out according to a disciplinary indicator. It would be wrong to give equal scores to students who complete the curriculum on time and to those who, for no good reason, are significantly late. In this case, students, although successfully, did the laboratory work on time, passed the module control, etc., receive only 1 point for the control element, regardless of the level of complexity of the tasks performed.

Table 2 shows an example of a variant for determining the semester rating of student performance.

Table 2. Scores ratings per semester

Form of control	Number of points	Number of control measures per semester	Total points
Attending classes	1	10	10
Performing laboratory work			
1st level of difficulty	0,5	10	5
2nd level of difficulty	1,5	10	15
3rd level of difficulty	2	10	20
Writing a report for each laboratory work	1	10	10
Practical protection of each laboratory work	1	10	10
test	30	1	30
Total for completing tasks:			
<i>1st level of difficulty</i>			65
<i>2nd level of difficulty</i>			80
<i>3rd level of difficulty</i>			100

3 Implementation and Evaluation

The results of the pedagogical experiment on the use of Maxima system in the process of “Operations research” teaching.

During 2016-2019 the experimental research has been conducted. During the experiment, the SCM MAXIMA was implemented in the process of "Operations research" teaching concerning the students of the Institute of Physics, Mathematics, Economics and Information Technology of the Drohobych Ivan Franco State Pedagogical University (education and qualification level "Bachelor", for the specialities 014 Secondary Education (Informatics). In the experiment, the specially worked out methodology of "Operations research" teaching using Maxima system was tested. In the experiment, on his forming stage, 50 students participated. The experiment confirmed the research hypothesis concerning the increase of the level of professional competences development

in the process of studies according to the worked out methodology. It also showed that using cloud technology students can achieve greater access to the means of research activities (it is possible to attain expansion of access to research activity facilities).

In the experiment, they involved both the local version of the system, installed on the student computer desktop and the cloud-based version that was posted on the virtual desktop.

Results formative stage of the pedagogical experiment in the control and experimental groups and comparative histogram distribution educational achievements students on the results of the final exam discipline "Operations Research" is shown in Fig. 3.

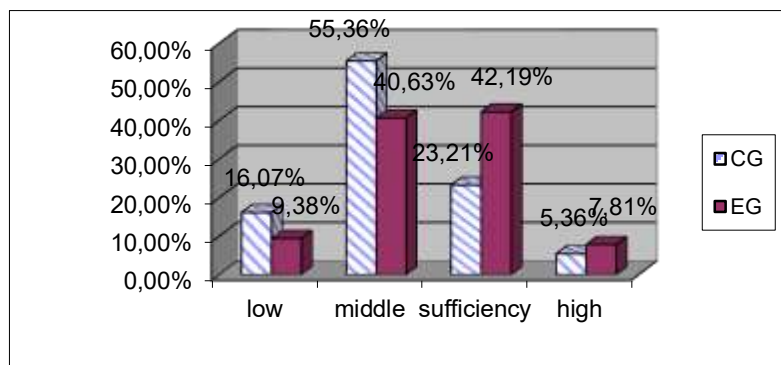


Fig. 3. A comparison of educational achievements of students on the results of final control the course "Operations Research" after the forming stage of the experiment

Processing of the experiment results and evaluation of the efficiency of the developed technique was carried out by methods of mathematical statistics [15]. The objective of the experiment was to identify differences in the distribution of certain characteristic (the level of formation of individual components of professional competence) comparing two empirical distributions according to the χ^2 - Pearson criterion, λ - Kolmogorov-Smirnov criterion [15].

χ^2 - Pearson criterion. The samples in the study are random and independent. The measurement scale is $C = 7$ categories (1-39, 40-59, 60-66, 67-74, 75-81, 82-89, 90-100). The number of the degree of freedom $\nu = C - 2 = 5$.

The null hypothesis H_0 : the distribution of the estimates for the student residual knowledge concerning the use of systems of computer mathematics in the control ($n_1 = 56$) and experimental samples ($n_2 = 64$) to the forming stage of the experiment do not differ ($i = 0, 1, \dots, 6$).

Q_{1i} – number of participants in the control group who scored i points;

Q_{2i} – number of participants in the experimental group who scored i points.

Alternative hypothesis H_1 : the distribution of the estimates for the student residual knowledge concerning the use of systems of computer mathematics in the control ($n_1 = 56$) and experimental samples ($n_2 = 64$) to the forming stage of the experiment differ ($i = 0, 1, \dots, 6$).

The value of χ^2 is calculated according to the formula

$$T_{\text{exp}} = \frac{1}{n_1 n_2} \sum_{i=0}^{C-1} \frac{(n_1 Q_{2i} - n_2 Q_{1i})^2}{Q_{1i} + Q_{2i}} \quad (1)$$

The results of calculating statistics of these samples are given in the Table. 3.

Table 3. The calculation of the χ^2 for the control and experimental groups before the forming experiment

I	Q1i	Q2i	S12i
0 (F)	0	0	0
1 (FX)	28	36	3136,00
2 (E)	36	38	1674,38
3 (D)	18	24	3510,86
4 (C)	16	18	30,12
5 (B)	10	6	23104,00
6 (A)	4	6	2560,00
T			2,372723

From the table of values, χ^2 for the level of significance $\alpha=0,05$ and number of degrees of freedom of $v = C - 2 = 5$ determine the critical value of statistics of $T_{\text{critical}} = 11,07$.

Since the obtained value $T_{\text{exp}} < T_{\text{critical}}$ ($2,372723 < 11,07$) does not fall in the critical region $[\chi^2, +\infty]$, this suggests that before the forming stage of the experiment the level of students' residual knowledge concerning SCM using in the control and experimental groups do not differ significantly.

The level of students knowledge on the course "Operations research" as well as professional disciplines was checked according to the results of complex state examination to justify the influence of methodology of SCM using as "Operations research" teaching tools on the increase of the level of some components of professional competence.

Null hypothesis H_0 : distribution of students estimations on "Operations research" in the control ($n_1 = 56$) and experimental samples ($n_2 = 64$) after the formative forming stage of the experiment do not differ ($i = 0, 1, \dots, 6$).

Q1i – number of participants in the control group who scored i points;

Q2i – number of participants in the experimental group who scored i points.

Alternative hypothesis H_1 : distribution of students estimations on "Operations research" in the control ($n_1 = 56$) and experimental samples ($n_2 = 64$) after the formative forming stage of the experiment differ ($i = 0, 1, \dots, 6$).

The calculation results of the statistics of these samples are given in Table 4.

The calculation of χ^2 criterion for the experimental and control samples after conducting the formative stage of the experiment showed that $T_{\text{exp}} > T_{\text{critical}}$ ($30,20408 > 11,07$). This is the reason for rejecting the null hypothesis.

The acceptance of the alternative hypothesis suggests that these samples have statistically significant differences, i.e., the experimental method is more effective than the traditional one.

Table 4. Calculation of χ^2 for the control and experimental groups after the formative experiment on the course "Operations research"

I	Q1i	Q2i	S12i
0 (F)	0	0	0
1 (FX)	18	12	30720,00
2 (E)	50	22	215168,00
3 (D)	12	30	79213,71
4 (C)	14	34	84672,00
5 (B)	12	20	15488,00
6 (A)	6	10	7744,00
T			30,20408

Taking into account that in the experimental groups the training of students was performed according to the developed methodology, it can be assumed that this contributed to the achievement of better results. Therefore, it is possible to speak of experimental confirmation of the hypotheses.

Summarizing, we conclude that the pedagogical experiment confirmed the hypothesis of the study. Analysis of the results indicates the increase in the level of formation of individual components of professional competence using the developed methodical system and, consequently, its effectiveness.

4 Conclusions and Prospects for Further Research

SCM implementation in the process of teachers training and also the process of computer science professionals training provides an opportunity to intensify the educational-cognitive activity of students, assists to development of their creative abilities, mathematical intuition and skills of research activities realization. SCM systematic using contributes to students attitude toward a computer as to the means of solving professional problems. Such students gain more knowledge not only in mathematical disciplines but also in computer science. As a rule, they have no psychological barrier to using sophisticated software tools. On the contrary, they are attracted by the programs created at a high professional level, and they notice the unique application possibilities of such systems. SCM is an environment for learning tools projecting and, consequently, can be used for the creation of innovative pedagogical technologies.

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The Digital Capabilities Model of University Teachers in the Educational Activities Context

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Abstract. The article analyses the views of researchers on digital literacy. It describes the meaning of the concept of digital capability. The authors summarize the common European standards and frameworks for teaching and evaluating digital capability. A model of the digital faculty of a university teacher based on the Jisc framework is described. It is adapted by the authors to the conditions of study at Ternopil Volodymyr Hnatiuk National Pedagogical University (Ukraine). The article describes and analyses the author's` research on measuring digital capabilities of the teachers. The criteria and indicators for measuring the digital faculty of a university teacher are revealed. Methods of research using methods of mathematical statistics are described. The authors identified and explained the correlations between individual distractors for each element of the framework. Some survey results were paradoxical, so a new study is needed. Based on this research, the authors have developed a program to improve the skills of teachers and their lifelong learning.

Keywords: model, digital capability, research, Pedagogical University, teacher's profile.

1 Introduction

Today, people need digital capabilities, digital well-being to live, learn and work effectively with modern ICT technologies. Accordingly, scientists create many models to adapt individual digital capabilities to real life and meet human needs. These models define new requirements, tasks, and opportunities. All of them are realized through the digitalization of modern society.

Nowadays, the question is, "What does it mean to be digital capable?" The answer depends on the individual and the organization in which he or she works or studies. Different organizations demonstrate different approaches to building both individual and organizational digital capabilities. The issue of digital ability at a deployment ICT technologies period is one of the most relevant and little studied issues. Research into both the personal digital ability of teachers and educational institutions as a whole is

now relevant. In general, the digital capability of the education industry is an integral part of the nationwide digital capability system, which is also characterized by many interconnected aspects.

The **purpose** of this article is to study the digital capacity model of teachers and its implementation at the Ternopil Volodymyr Hnatiuk National Pedagogical University (TNPU).

2 The theoretical basis of research

The concept of digital literacy was preceded by the concept of digital capability. It has been widely studied in the 1990s [4]. It includes information, computer, network and media literacies. Modern researchers often define digital literacy as the ability to use modern digital technologies effectively and safely in work, study, professional and personal development. For over 20 years, the concept of "digital literacy" is constantly transforming.

P. Gilster defined digital literacy as the ability to understand and use information in a variety of formats from many sources. He highlighted four key competences of digital literacy: knowledge collections, content assessment, Internet search and navigation [12]. C. Pool studied the development of critical thinking in the Internet age [23].

In today's context, digital literacy is often viewed by researchers as a minimal skill set. These skills will allow the user to work effectively with software or to perform information retrieval tasks. This definition is functional. It identifies the basic skills needed to perform basic operations [7].

Specialists in the US Educational Testing Service have defined digital literacy as the ability to effectively use digital technologies, communications and networks to operate in the information society and solve important information problems. Scientists have included components in digital literacy such as the ability to use digital technology for research, evaluation and transmission of information. In addition, they noted that a digitally competent person should have an understanding of ethical and legal issues related to access and use of information [17]. This means that a person can communicate and interact with others, achieve economic success, and actively participate in social communities and collaborate on the Internet. That is, this approach states that digital literacy has become a skill that people need to process information and personal development [20].

A. Burn and J. Durran explored the concepts of digital literacy through the development of modern content forming technologies, digital economy competencies and digital skills in frameworks of teaching disciplines. In their view, the most significant feature of digital literacy is the combination of "information" with "media literacy." Scientists have found that users often have difficulty in distinguishing between these concepts [8].

Some theoretical schools have commented on the term "literacy". Their scientists believed that literacy was what usually happens at the beginning of the educational process. The problem for these researchers was to replace the term "literacy" with a

broader one. This new concept should describe common digital practices, not just complex skills. This is how the term "digital literacy" was replaced by the term "digital capability".

A. Bartlett-Bragg says that digital capability is not just about ICT competencies. It exists at the intersection of people and technology, work and learning [4]. Therefore, nowadays, scientists are studying both personal and collective digital abilities.

Digital capabilities have been identified in the works of E. Bennett, S. Folley and H. Beetham [6], [5]. In particular, researchers compared professional teaching identity with their digital ability. Professional identity has also often been the subject of research. E. Bennett, S. Folley explored digitally capable teachers. These specialists showed confidence, readiness for research, resistance to failures. Scientists concluded that these characteristics defined teachers as successful practitioners, and were not determined solely by their technical skills. T. Owens described combining both identities and analysed learning experiences in the context of digital capabilities [22]. Specialists and teachers who were able to work in digital mode were studied in his work.

Digital capability is the term used to describe the digital practices that people and organizations need. Such practices in the modern world are necessary for the successful operation of the individual and the good functioning of the business. By 2015, scientists had learned that creating a person's identity in the digital space, engaging it in the digital space, and performing digital activities provide many opportunities [22]. At the same time, these opportunities contribute too many threats. Researchers had concluded on the importance of building functional digital skills in the context of personal well-being, awareness of the integrity of the individual in the digital space [21].

Therefore, the concepts of "digital literacy" and "digital capability" are not completely synonymous. Digital literacy is a minimum set of skills for assessing the information it uses to gain knowledge and solve problems. Digital capability is a systematic activity aimed at prospering people and organizations in the modern world and ensuring their information security.

In this regard, the strategic solution was the creation of a digital capacity framework. These digital frames are most useful for activities such as:

- combining people 's digital abilities;
- embedding digital ability into specific subject areas;
- mapping of digital experience of personnel with different roles;
- structuring professional development;
- assessment of digital ability level.

Depth of digital ability may vary. One of the most advanced is the EU's digital competency assessment system. It includes a number of institutions, indicators and programs. There are currently pan-European standards for teaching and evaluating digital capability such as:

- International Computer Driving Licence (ECDL/ICDL). Its certificates are valid in almost all European countries. The organization accredits exam centres - companies, schools, non-governmental organizations that conduct exams based on franchising.

The curriculum consists of 18 modules at three levels: basic, intermediate and advanced [14].

- Digital Competence Framework for citizens (DigComp). It was created by the Joint Research Centre of the European Commission. The latest version of this framework provides for eight skill levels. Based on this, educational organizations can create a basic digital capability course [9].
- The Digital Economy and Society Index (DESI). It allows comparing European countries by indicator of digital skills, however is not suitable for certification of skills, training or research [24].
- The European Certification of Informatics Professionals (EUCIP). The frame is aimed at computer scientists. It is used by vocational education institutions to develop and certify training programs [25].
- The European e-Competence Framework (eCF). The framework has the status of an official European standard for ICT professionals. It contains 40 competencies applicable in the workplace. Suitable for use by corporations, small and medium-sized enterprises, educational institutions [26].
- The Jisc Framework. It focuses on emerging digital realities and provides an overall map of digital capability development at both basic and advanced levels. The Jisc framework was developed with the involvement of stakeholders. It is now the global benchmark for digital capability. It provides various examples of digital practices, tools and resources [11].

To create a model for our university's digital faculty and further research, we chose the Jisc framework. In addition, we used the models previously developed by us [3], [2]. The Jisc framework describes digital capability as a tool for the prosperity of educational institutions in the digital world. It offers a way of thinking about how teachers and students can successfully operate in a digitalized society.

The Jisc framework distinguishes between organizational and individual capacity. The concept of individual digital ability interprets learning as an individual result of a person, his or her effort and realization of individual opportunities. But learning must at the same time be a product of a supportive context. This happens when a person is in a supportive environment, has the necessary resources, and cooperates with the right people [13]. And the university should be responsible for providing that context. [15]. What it means to be capable of digital technology depends on each person. This depends on individual requirements, subject matter specialization, and career choices, personal and other factors.

The Individual Digital Capability Framework contains six predefined elements:

- ICT Proficiency (functional skills).
- Information, data and media literacies (critical use).
- Digital creation, problem solving and innovation (creative production).
- Digital communication, collaboration and partnership (participation).
- Digital learning and development (development).
- Digital identity and wellbeing (self-actualising).

The Jisc framework has created a series of role profiles that look at six elements of digital capability in the context of different roles. The main ones are the teacher's and the researcher's profile. Each profile demonstrates how new practices emerge and how teachers can use their own digital skills in different aspects of their professional role.

Let's take a closer look at the elements of the Jisc framework.

There are different views about *ICT Proficiency* being included as a separate element of the Jisc framework. However, all scholars agree that ICT knowledge is the basis for developing all other capabilities [16].

In the *Information, data and media literacies* element, "information literacy" and "media literacy" are aligned. There are two different discourses here, one focused on information and management. It applies to library science and digital technologies. The second discourse concerns the understanding of digital media related to communications and media research. The boundaries between data literacy and information literacy are difficult to define. Scientists and teachers have the notion that "data" is the basis of research and accountability, and "information" is the result of a secondary analysis. Therefore, information, media and data literacy are considered as separate but closely related elements of digital capability. According to them, operations such as critical use, analysis, evaluation are applied. For example, actions on the proper use of digital data and information may be generalized to the concepts of "critical use of information" or "critical thinking".

The element of *Digital creation, problem solving and innovation* covers the many ways in which teachers generate original ideas and results. For example, teachers are often innovative practitioners. The element of Digital creation, problem solving and innovation was expanded by the authors of the framework. This was done to make it more inclusive of "innovation" and other forms of creativity. Original thinking is central both to researchers who need to generate new ideas and to teachers who are developing in the professional digital space. Teachers can be innovators both in their organizational activities and in specialized subject areas. The focus is on the use of digital technologies to develop and disseminate ideas and practices. This element includes creativity and innovation as separate but related opportunities. They can be described as "creative production".

The element of *Digital communication, collaboration and partnership*, reflects the fact that many aspects of social and cultural life are now online. The authors of the framework believe that this aspect of digital capability needs to be defined more broadly. The practical aspects of citizenship belong to this element. But the development and expression of personal values through civic activity can be seen as an aspect of identity. Even though critical use and creative production can be done through digital tools, participation can only take place with respect to other people. This activity is usually mediated through computer networks. The element Digital communication, collaboration and partnership summarizes these elements.

The element of *Digital learning and development includes planning*, reflection and all aspects of self-development in the digital environment. The university's teachers are responsible for the education of future generations. The framework describes the digital opportunities for organizing the educational process. There are now specialized training and assessment systems. They involve the use of special learning support applications

(e.g., quizzes, animations, virtual worlds) and more general learning support applications (such as tools for writing, discussing, collaborating, commenting, feedback).

The element of *Digital identity and wellbeing* is quite important. Therefore, the authors of the framework added it as a separate component. However, it is sometimes associated with "digital identity". If the digital capability of the Jisc framework expresses "what I can do", then digital identity and well-being answers the question of "who am I when I do it". In the process of actualizing oneself as a digital personality, one or more manifestations of digital identity, digital participation styles, values, and a critical stance on digital ability develop.

As a result, if digital identity is at the apex of the pyramid of digital capability development, and ICT knowledge is at its core, then other elements are examples of existing digital practices.

3 Experimental study

Based on this framework, we have created a digital capabilities model of university teacher. It provides an opportunity to implement the Jisc framework in the local context of Ukrainian higher education teaching practice. Our next step was to bring this model closer to existing role definitions and standards. We have modified the Jisc model based on professional Ukrainian standards for teaching staff and for researchers. This was done because teachers in universities combine both roles [18], [19], [10], [1].

In 2018-2019, we conducted an experimental study. Its purpose was to study the digital capability of TNPU teachers. During the research we used a set of research methods, such as analysis of scientific and educational-methodological literature, official documents of the European Union, models of development of digital capabilities of the leading universities in the world and the government of Ukraine. They became the theoretical basis for solving the problem. We also used empirical methods such as surveys and surveys of university teachers. This gave us an opportunity to find out the attitude of teachers to the problem of developing their digital capabilities. We used the methods of mathematical statistics to process the data obtained, analyse and interpret the study results.

The study was conducted during the following stages:

1. Study of the studies that explored the digital capabilities of university teachers. Analysis of models of development of digital capabilities and choose the most appropriate framework.
2. Adaptation of the chosen model taking into account the specifics of the functioning of our university.
3. Choice of experimental research methods. We have created a self-assessment questionnaire by teachers of their own digital capabilities. The strategy of this study was to use an online survey.
4. Statistical processing of experimental data and interpretation of the results.

We have created a self-assessment questionnaire for teachers of their own digital capabilities. We have created a self-assessment questionnaire for teachers of their own

digital capabilities. The questionnaire contained 58 questions. They have been grouped into five sections according to the elements of the Jisc framework (see Table 1). We considered the sample as unrepresentative.

Table 1. The structure of the author's model of digital capabilities

Element	Group of Distractor	Code and Description of Distractor	
<i>Digital proficiency</i>	<i>Digital proficiency</i>	DProf1 – use ICT devices, software and services	
		DProf2 – using subject-specialist ICT devices	
		DProf3 – stay up to date with digital technologies as they evolve	
	<i>Digital productivity</i>	DProd1 – work with software to achieve teaching and assessment tasks	
		DProd2 – use digital tools to work productively and efficiently	
		DProd3 – use institutional ICT systems for teaching, assessment	
<i>Information, data and media literacies</i>	<i>Information literacy</i>	DProd4 – adapt ICT systems, applications to suit personal needs	
		IL1 – find, evaluate, manage, share digital content for learning	
		IL2 – support learners in their use of content, including academic, professional and open content	
		IL3 – interpret information for academic and professional purposes	
	<i>Data literacy</i>	IL4 – know the rules of copyright and plagiarism and alternatives	
		DL1 – collate, manage, access and use digital data in the medias	
		DL2 – record learner-related data in digital systems as required	
		DL3 – manage personal data securely	
	<i>Media literacy</i>	ML1 – critically read and interpret messages from digital media	
		ML2 – support learners in their use of digital media	
		ML3 – choose and use media resources suitable to students' needs	
		ML4 – know the rules of digital copyright and alternatives	
<i>Digital creation, problem-solving and innovation</i>	<i>Digital creation</i>	DCr1 – edit, remix, repurpose digital media to meet learning needs	
		DCr2 – produce digital materials to communicate learning content	
		DCr3 – design digital tests, quizzes and assessment tasks	
		DCr4 – design digital activities for different teaching contexts	
	<i>Digital research and problem solving</i>	DR1 – collect, understand and use evaluation teaching/learning data	
		DR2 – use the outcomes of digital scholarship as learning resources	
		<i>Digital innovation</i>	DIn1 – investigate and implement new approaches to teaching
			DIn2 – identify problems and challenges in digital learning
<i>Digital communication</i>	<i>Digital communication</i>	DCom1 – use digital communications to support learning	
		DCom2 – communicate ideas in accordance with different cultural	
		DCom3 – consider the communication needs of learners	

<i>collaboration and participation</i>	<i>Digital collaboration</i>	DCom4 – support learners to communicate effectively
		DCom5 – respect others in public communications
		DCol1 – participate in digital teams and working groups
		DCol2 – collaborate effectively in digital spaces
		DCol3 – support learners to collaborate using shared digital tools
	<i>Digital participation</i>	DP1 – participate in digital networks with learners and teachers
		DP2 – share learning and teaching materials, educational resources
		DP3 – facilitate learning groups and networks
	<i>Digital learning</i>	DP4 – behave safely and ethically in networking situations
		DL1 – use digital networks to undertake professional development
DL2 – identify and take up opportunities for professional development in digital learning, teaching and assessment		
DL3 – reflect on personal practices with technology		
<i>Digital learning and development</i>	<i>Digital teaching practices</i>	DTP1 – design and plan courses of study to include digital issues
		DTP2 – use digital tools to plan, design and review courses
		DTP3 – design and plan digital learning and assessment activities
		DTP4 – adapt teaching in response to feedback from learners collected
		DTP5 – facilitate learning in digital settings
		DTP6 – use digital technologies to support in-class learning
		DTP7 – use digital tools to record learning events/data
		DTP8 – work with other professionals
		DTP9 – use digital tools in support of assessment
		DTP10 – design assessment activities to demonstrate digital capabilities
<i>Digital identity and well-being</i>	<i>Digital identity</i>	DI1 – develop a positive digital identity as an educator
		DI2 – collate and curate professional materials
	<i>Digital wellbeing</i>	DW1 – look after personal health, safety, relationships and balance
		DW2 – act with respect for the health of others and natural environment
		DW3 – participate in digital safety and cyber-bullying initiatives
		DW4 – ensure equality of access to digital opportunity
		DW5 – balance digital with real-world interactions appropriately

Through the online form we interviewed 96 teachers from all TNPU faculties. Since the questionnaire contained many questions, we did not put any time limits for filling it out. Teachers were asked to give a self-assessment of the level of development of their own digital capabilities. The general form of the following question was used: "Please rate your digital capability ..."? Assessments were conducted on a four-point Likert-like scale ranging from 0 points (no digital capability) to 3 points (high digital

capability). For example, one of the questions on the questionnaire was: "Please evaluate your own level of use of training ICT devices, systems, tools and services."

The use of this method allowed obtaining quantitative data of respondents' self-esteem. In our study, a sequential rating scale was used to express respondents' level of digital ability development. However, the use of the Likert scale in the study had shortcomings such as the avoidance of respondents' maximum or minimum scores, the presentation of not sufficiently candid estimates, the irregularity of the interval scale. Therefore, when formulating the questionnaire, we met the following requirements:

- use of unipolar rating scales in all matters;
- removal of neutral response;
- avoid formulating questions in a negative form;
- concise explanation of questions in the form of simple sentences.

The questions are focused on measuring the latent variable. In our study, this variable is the measure of digital capabilities. The respondent's assessment of each of the statements of the questionnaire can be considered as a function of the general latent factor. Therefore, we considered that a greater positive assessment of a respondent's assertion corresponds to a higher level of development of his or her digital capabilities.

We have created a spreadsheet to process the results. It contained all the data received from the respondents. Since the questionnaire contained a large number of questions, here is a snippet of this table for the items "Digital proficiency" and "Information, data and media literacies" (see Table 2):

Table 2. Self-assessment data for the element "*Digital proficiency*"

<i>Digital proficiency</i>							
<i>Respondent's number</i>	<i>Digital proficiency</i>			<i>Digital productivity</i>			
	<i>DProf1</i>	<i>DProf2</i>	<i>DProf3</i>	<i>DProd1</i>	<i>DProd2</i>	<i>DProd3</i>	<i>DProd4</i>
1	3	2	1	1	1	2	0
2	2	1	1	2	2	3	1
3	2	1	0	1	1	1	0
4	1	1	0	0	0	1	0
...
96	2	2	1	3	3	3	2

The full survey table can be downloaded from the link <https://drive.google.com/open?id=1DTMjy5W6w5P5dHUPC3Yc6auRmJ110QSE>

We summed up all the distractors of each element group by the teacher's scores. The obtained total score allowed to determine the total assessment of the respondents to the studied distractor.

Figures 1-3 contain a graphical representation of the results obtained:

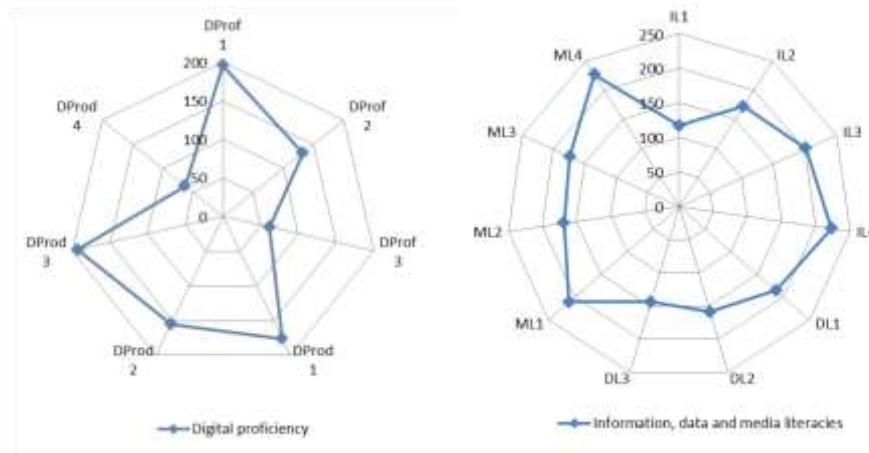


Fig. 1. Summative teachers' assessments of the elements "Digital proficiency" and "Information, data and media literacies"

Figure 1 shows that in the "Digital proficiency" element, teachers rated their own digital capabilities most highly, such as "Use ICT devices, software and services" (Dprof1) and "Use institutional ICT systems for teaching, assessment" (Dprod3). Therefore, it can be considered that teachers have good knowledge of office software and university training services. In addition, "Stay up to date with digital technologies as they evolve" (Drof3) and "adapt ICT systems, applications to suit personal needs" (Drod4) distractors were rated quite low. Therefore, it can be concluded that teachers are not yet ready to select specialized software and adapt it to their own professional needs.

In the element "Information, data and media literature," the possibilities concerning copyright and related rights (IL4, ML4) and critical assessment of information (ML1) were most highly appreciated.

Based on the analysis of the element "Digital creation, problem-solving and innovation" (see Fig. 2), we concluded that teachers are not ready to use innovations, create new digital learning resources and solve related problems. At the same time, teachers find themselves competent enough to design digital tests, quizzes and assessment tasks (Dcr3 distractor). Among the items of the "Digital Communication and Cooperation element" the distractor "Participating in digital networks and social media relevant" (DP1), as expected, received the highest score.

We were surprised by the low score of the "Consider the communication and access needs of different learners" (DCom3 distractor). In particular, in the face of modern challenges, these digital capabilities need improvement and refinement. Therefore, we can say that the explanation for this phenomenon requires a separate study.

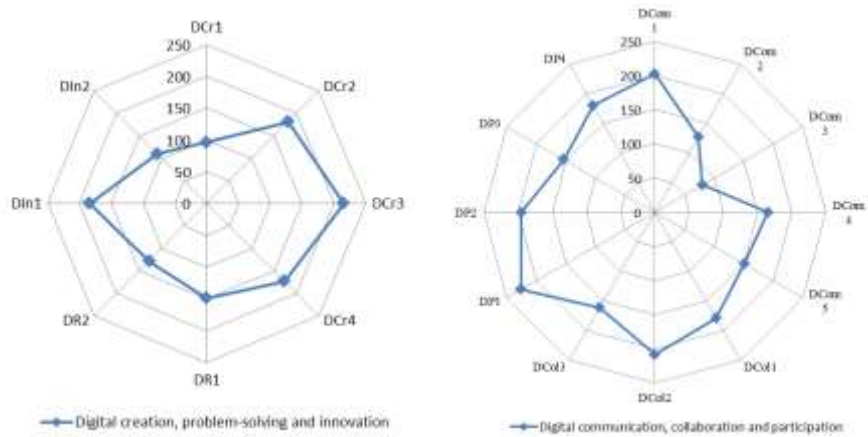


Fig. 2. Summative teachers' assessments of the elements "Digital creation, problem-solving and innovation" and "Digital communication, collaboration and participation"

Most evaluations of Digital Learning and Development and Digital Identity and Well-being distractors may be considered acceptable (see Fig. 3). DL3 distractor is negatively distinguished from this distribution. This means that TNPU lecturers do not think too often about methods of personal learning, teaching and assessment using ICT technologies.

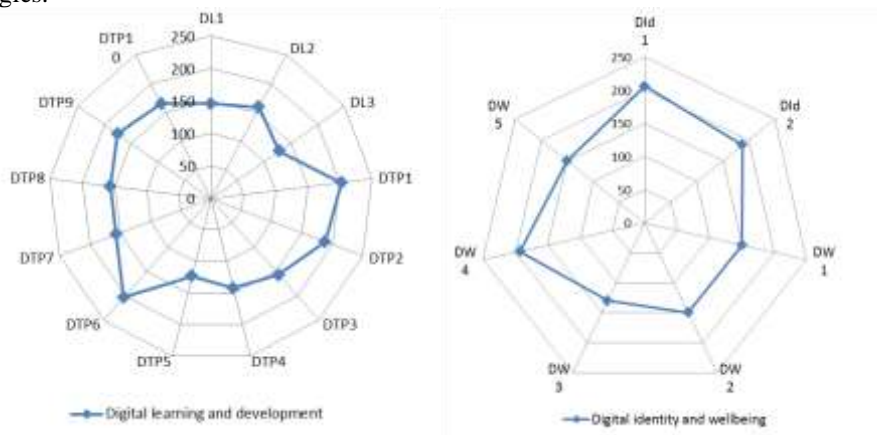


Fig. 3. Summative teachers' assessments of the elements "Digital learning and development" and "Digital identity and wellbeing"

The processing and analysis of the results of the study involved the use of the Likert scale and the Spearman rank correlation coefficient. The result of this use was to detect the existence of correlation relationships between individual distractors for each framework element. At this stage of the study, we built tables to calculate the Spearman rank correlation coefficients.

The following table presents the results of the calculation of the DProf1 distractor.

Table 3. Calculation of the correlation coefficient for the DProf1 distractor

Respondent's Number	Respondent's Sum	DProf1	DProf1-Sum	Rank1 (DProf1)	Rank2 (DProf1-Sum)	Rank1-Rank2	(Rank1-Rank2) ²
1	10	3	7	12,5	59,5	-47	2209
2	12	2	10	51	29	22	484
3	6	2	4	51	88	-37	1369
4	3	1	2	86,5	93	-6,5	42,25
...							
96	16	2	14	51	5	46	2116
Total	977	196	781	4656	4656	0	88313,5

Let's explain some of the column headers in the Table 3:

1. Respondent's Sum – the sum of the points of all distractors from the Digital proficiency element;
2. DProf1-Sum – the difference between the distractor score (DProf1 column) and the sum from item 1 (Respondent's Sum column);
3. Rank1 – the rank (taking into account the correction coefficient for the associated ranks) of the respondent score among the scores of all teachers;
4. Rank2 – the rank of difference (DProf1-Sum) obtained in paragraph 2.

Similarly, we calculated the data in all tables according to all 58 distractors of the questionnaire. Spearman's rank correlation coefficient was calculated for each distractor by the formula:

$$r_s = \frac{6 \sum_{i=1}^n (Rank_1 - Rank_2)^2}{n(n^2 - 1)} \quad (1)$$

where r_s is Spearman's rank correlation coefficient, Rank1-Rank2 is the rank difference, $n = 96$ is the number of rank pairs (number of respondents).

The values of all obtained correlation coefficients are shown in table 4:

Table 4. The values of the correlation coefficients for all distractors

Distractor	r_s	Distractor	r_s	Distractor	r_s
DProf1	0,4	DCr1	0,72	DL1	0,48
DProf2	0,33	DCr2	0,73	DL2	0,54
DProf3	0,34	DCr3	0,61	DL3	0,44
DProd1	0,68	DCr4	0,72	DTP1	0,83
DProd2	0,74	DR1	0,24	DTP2	0,81
DProd3	0,69	DR2	0,22	DTP3	0,89

DProd4	0,69	DIn1	0,24	DTP4	0,82
IL1	0,45	DIn2	0,23	DTP5	0,82
IL2	0,46	DCom1	0,58	DTP6	0,81
IL3	0,43	DCom2	0,53	DTP7	0,89
IL4	0,49	DCom3	0,5	DTP8	0,89
DL1	0,41	DCom4	0,49	DTP9	0,84
DL2	0,44	DCom5	0,45	DTP10	0,87
DL3	0,35	DCol1	0,36	Did1	0,45
ML1	0,46	DCol2	0,3	Did2	0,43
ML2	0,5	DCol3	0,33	DW1	0,89
ML3	0,48	DP1	0,48	DW2	0,89
ML4	0,45	DP2	0,54	DW3	0,81
		DP3	0,44	DW4	0,71
		DP4	0,53	DW5	0,89

We interpreted the results based on the Cheddock Scale [27]. The limits of the correlation coefficients obtained allow us to estimate the close relationship between the distractors inside the element. Therefore, according to the Cheddock scale, we have determined the following coefficient limits:

- 0,1-0,3 – weak connection;
- 0,3-0,5 – moderate relationship;
- 0,5-0,7 – average connection;
- 0,7-0,9 – strong bond;
- 0,9-0,99 – very strong relationship.

A graphical representation of the obtained correlation coefficients for all 58 distractors is shown in figure 4.

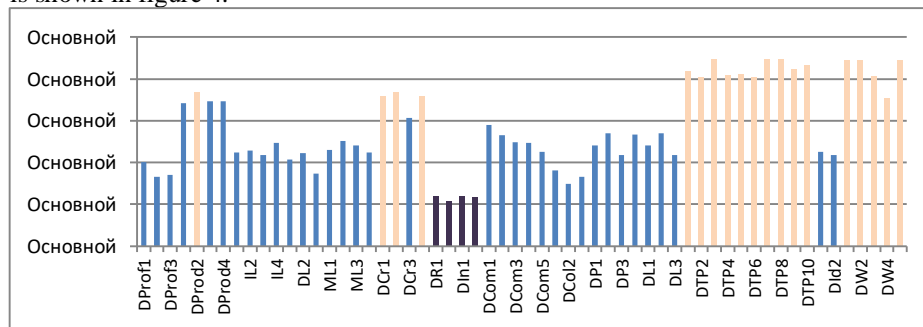


Fig. 4. Diagram of obtained Spearman's correlation coefficients

In the diagram, distractors with low correlation coefficients are coloured dark. Colours corresponding to high r_s distributors have a light colour.

The diagram shows that there is a strong link between all distractors in elements such as "Digital teaching practices" and "Digital wellbeing". This means that the distractors of these elements are selected and identified as correctly as possible. A similar situation with the "Digital creation element".

Unfortunately, the questionnaire contained 4 distractors with low correlation coefficient – DR1, DR2, DIn1, and DIn2. They all belong to the element of "Digital creation, problem-solving and innovation". It can be assumed that the distractors of this element relate to scientific activity. Therefore, we can assume that teachers believe that their own functional skills as a scientist are not as advanced as teaching.

Recalling that some of these distributors had a low overall sum, it could be concluded that such a questionnaire should be adjusted for further research. All other distractors of the questionnaire generally correlate quite well within their elements. This indicates that the questionnaire has sufficient quality and validity.

4 Conclusions

The paper analyses the views of researchers on digital literacy. On this basis, the content of the concept of digital capability is revealed. Digital capability consists of skills, knowledge and understanding. They allow critical, creative and secure use of digital technologies. It is about cultural and social awareness and functional skills of the individual. It is also important to know when digital technologies are appropriate and useful for the task and when not.

The term "digital capability" is associated with such frameworks as UCISA and Jisc. According to these models, digital literacy is made up of elements. These items help to define how the term is used to evaluate teachers' digital ability.

The Jisc framework has become a methodological basis for the study digital capabilities of the university's teachers. It is mainly intended for the evaluation of individual professional development. In this study, the digital capability model was tested in the context of teachers' educational and research activities.

An important role in the development of digital capability is the systematic use of ICT-technologies in the educational process. The digital capability is closely related to the professional activity of the teacher. Digital abilities are closely related to the professional activities of the teacher. It involves the use of modern digital technologies, efficient delivery of knowledge, involving students in practical activities, organization of monitoring and evaluation of academic achievements. Compliance with these requirements ensures the development of students' digital capabilities.

Questionnaire was used to develop approaches to assessing the digital capabilities of teachers and collecting relevant data. The questionnaire was created on the basis of the Likert scale. The correlation within the elements was verified using the Spearman correlation coefficient and the Cheddock scale.

Based on the analysis of the results, the specialists of the Department of Informatics of the TNPU developed teacher's development programs for their lifelong learning. Based on these programs, trainings are designed to help university teachers develop

their own digital capabilities. In modern conditions, they are very important, in particular for distance learning. The educational offer of advanced training courses is quite broad. These are digital skills development courses and trainings that cover topics such as:

1. Distance learning organizations using digital technologies. This will enable the use of technological infrastructure and the digital environment to ensure inclusive experience for all learners.
2. Designing digital capabilities in the curriculum. The purpose of this training is to achieve mastery in digital curriculum design. According to these programs, teachers will prepare students for successful learning and living in the digital world. The training is aimed at developing digital creativity and problem solving skills.
3. Digital educational leaders program. It provides the digital capability and success of the entire educational institution.
4. Students' employment development skills. The program provides the skills, knowledge and experience of graduates using digital technologies.
5. Supporting the digital identity of teachers. The training will help educators make informed and responsible choices when using digital technology in their professional activities.

We hope that these trainings will help educators to achieve high digital ability and meet today's challenges. It provides guided paths through teacher support scenarios. We believe that these, modern educators will work effectively in the fast-paced, complex digital world that is shaping new learning realities.

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The Use of Electronic Open Journal Systems in Scientific and Pedagogic Research: Results of Experiment

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Abstract. The article deals with the problem of the use of electronic open journal systems in scientific and pedagogical research as well as the formation of ICT competence of researchers on the use of such systems. The concepts of electronic journal system (EJS) are considered. The most common kinds of electronic journal systems are revealed (proprietary, local (in-house), open and cloud journal systems). The criteria for accessing the effectiveness of the electronic open journal systems (EOJS) use in scientific and pedagogical research are described (normative, organizational and communication, effective), as well as their indicators. The organizational and pedagogical model of EOJS use in scientific and pedagogical researches is developed. The definition of "ICT competence of researchers on the use of EOJS in scientific and pedagogical research" is provided; its components are described; criteria (axiological, cognitive, praxeological, adaptive) and indicators of its formation are defined. The model of formation of this competence is provided. The main stages of the experimental process (2010–2018) are described. The results of the formation of ICT-competence of researchers and information-analytical monitoring of the scientific journals of the National Academy of Educational Sciences of Ukraine are presented.

Keywords: Open Journal Systems, Scientific E-Journal, ICT Competence, Researchers.

1 Introduction

The traditional model of scientific communication is based on a system of printed scientific publications (journals, monographs, collections of conference materials). Today the scientific content is presented mainly in electronic format. The central element of the modern model of scientific communication is the electronic scientific journal. That's why, the information and communication technologies (ICT) for the deployment and support of scientific periodicals on the Internet are becoming widespread. The type of such ICT is the electronic journal system (EJS). It supports the processes of user's registration, submission and initial review of manuscripts for adherence to editorial requirements; the appointment of reviewers, double-blind scientific review, monitoring of review process, collective editing of manuscripts,

editing metadata, maintaining text, graphics and video files, creation and publishing of collections of articles, their long-term storage, collection of usage statistics, control of access levels, subscription, etc.

Moving the publishing process to the online environment should be achieved by a careful selection of the service that will best meet with the needs of individual researchers, scientific institutions and journal editors. In the same time, a sufficient level of researchers' ICT competence to use such systems should be the key to effective scientific and pedagogical research.

Analysis of recent studies and publications. The problem of electronic journal systems using for support electronic scientific periodicals has been partially investigated in the following areas:

- the definition of the concept of electronic journal systems [1]–[5];
- a description of the design, development and practice of the use of individual EJS samples [2], [3], [6]–[16]; comparative analysis of EOJS [4], [21], [22], [37].
- functional aspects of EOJS [1], [3], [10], [12], [17]–[20];
- use of the Open Journal System (OJS) software platform to create and support university e-repositories and of scientific journals collections [5], [23]–[29];
- support for educational publications on the base of Open Journal System [30], [31], as well as the socio-psychological aspects of this process [32];
- teaching of master's students the basics of scientific activity [33];
- automation of data export from OJS to scientometric databases [34].

The research hypothesis: implementation of the specially developed method in the process of training and in service training of researchers will increase the level of formation of their ICT competency on the use of electronic open journal systems as well as the level of efficiency of these systems use in scientific and pedagogical research. The **purpose of the article** is to present the results of experimental verification of this hypothesis.

2 Theoretical Background

The analysis of scientific sources shows that there is no agreed position on the established name of technologies to support the editorial and publishing process. Scientists use about twenty synonymous terms: electronic journal management systems [1], [9], [18], [19]; e-journal management systems [11]; e-journal publishing systems [11]; web-based journal management systems [17]; electronic publishing systems [21]; open-source electronic publishing systems [21]; e-publishing systems [6]; open-source online publishing systems [7]; online peer review systems [7]; computerized review systems [20]; online submission and peer-review systems [12]; web-based manuscript submission and peer-review system [9]; online journal systems [36]; online publishing systems [36]; digital publishing systems [37]; journal publishing systems [38]; journal management systems [38]; los sistemas de gestiyn editorial [38]; electronic management systems of the peer review process [39]; electronic journal publishing systems [40]; web-publishing systems [41], web-based peer-review systems [42]; open source journal management systems [43].

Summarizing the interpretation given in these sources, we offer the following definitions:

- **electronic journal system (EJS)** is the software that automates the support and management of the editorial and publishing process of scientific journals;
- **electronic open journal system (EOJS)** the open-source software platforms that provide organizational and decentralized remote management of the full cycle of the electronic scientific journals editorial and publishing process: submission, review, copyediting, proofreading, layout and articles publication, as well as their preservation, dissemination, and indexing in the Internet.

2.1 Types of electronic journal systems

In the early 2000s, Wood D. [13], Shapiro K [3], Ware M. [12], McKiernan G. [10] performed a comparative analysis of popular electronic **proprietary journal systems**, such as *PeerTrack™*, *Bench>Press™*, *EdiKitSM (bepress)*, *ESPERE*, *Manuscript Central™*, *Rapid Review®*, *Editorial Manager*, *eJournalPress (EJPress)*, *FontisWorks*, *XpressTrack*. Notwithstanding the slight differences in the interface, functionality and cost of licenses, a "virtual publishing office" with appropriate mechanisms for receiving, processing, distributing and revising manuscripts was implemented in all the above-mentioned platforms.

Further, some scientific institutions and publishers made experimental attempts to develop **local (in-house) systems** [2], [7], [9], [11], [14], [18] for the support of their own electronic journals. Such systems become customizable to the specific needs of the publisher, adaptable to any workflow changes in the future and are independent of a third-party developer. Samples of local electronic journal systems are *EJMS – Electronic Journal Management System*; *SXC-JMS (St. Xavier's College – Journal Management System)*; *BMIF's Online Peer Review System*; *BMIF – Mathematics, Informatics, Physics Series – Bulletin of PG University of Ploiesti»*; *IAJIT OpenConf Journal Management System (IAJIT JMS)*; *Electronic Journal of University Malaya (EJUM)*; *Электронная редакция журналов СПбПУ*; *Elsevier Editorial System (EES)*; *ACS Paragon Plus Environment*; *Begell House Journals Online Submission System*; *Independent Journal Program*.

Developing countries do not have sufficient financial support and the necessary technical facilities to publish scientific periodicals, and therefore cannot incur significant software acquisition costs. That is why, over the last decade, numerous attempts have been made to develop freely distributed software platforms to support electronic scientific periodicals, such as electronic **open journal systems** [4], [5], [21], [22]. The most popular examples of EOJS are *EPublishing Toolkit*; *GAPworks*; *SOPS (SciX Open Publishing Services)*; *Topaz*; *DiVA (Digitala Vetenskapliga Arkivet)*; *Érudit*; *DPubS (Digital Publishing System)*; *HyperJournal*; *E-Journal*; *Ambra*; *Open Journal Systems (OJS)*.

Using such systems allows for simplified setup, more powerful functionality and reduced costs for publishing a scientific product. However, for the functioning of the entire above electronic journal systems, it is crucial to have a database located on a web server with constant uninterrupted access to the Internet. This involves acquiring or leasing by scientific institution a web server by a scientific institution and ordering the services of a competent system administrator.

A new trend to support the publishing of scientific periodicals is the development of so-called **cloud journal systems** [6], [8]. They allow users to use the service over the

Internet. Namely, to move all editorial processes to remote servers that will deliver the publishing environment to a large number of clients continuously using a single platform. Examples of cloud EJS are projects *Scholastica*; *Cloud Publications*; *Cloud Journals*.

Based on detailed comparative analysis [30], practical experience and wide geographic of use we conclude that the best way to support electronic journals is to use open electronic journal systems. In particular, Open Journal Systems can be recommended to scientific institutions and editorial boards, as it enables the editorial team to automate and simplify technological tasks to the greatest extent possible.

2.2 The organizational and pedagogical model of EOJS use in scientific and pedagogical researches

The **author's method** is based on the organizational and pedagogical model of EOJS use in scientific and pedagogical researches (see Fig. 1). It consists of target, procedural, evaluation and result components as well as the model of formation of the researchers ICT competence on the use of EOJS in scientific and pedagogical research. (Fig. 2). The procedural component of this model describes the seven stages of the procedure of the electronic scientific journal implementation by using EOJS (predictive, organizational, technical and technological, preparatory, practical, generalizing and perspective). The evaluation component of the model reveals **the criteria of efficiency of the electronic open journal systems use in scientific and pedagogical research** – the indicators for the evaluation of the efficiency of the EOJS use in scientific and pedagogical research. The criteria and indicators we propose are presented in the Table 1:

Table 1. Criteria and indicators of efficiency of the electronic open journal systems use in scientific and pedagogical research

Criteria	Indicators
Normative	Compliance with regulations on the functioning of electronic scientific journals.
	Compliance with the requirements for the structure, design, and content of electronic periodicals.
	Compliance with international publishing standards.
Organizational and communication	Time for preparing, publishing and distributing published content.
	The number of registered users/authors/readers and their geographical distribution.
	The number of manuscripts received/reviewed/published per month (including English).
	Percentage of accepted/rejected manuscripts.
Productive	Availability of tools for supporting scientific communication during the editorial and publishing process participants.
	The developed ICT competence of researchers in the use of electronic open journal systems in scientific and pedagogical research.
	Inclusion of an electronic scientific journal in the leading international scientometrics and abstract databases; growth of scientometric indicators of journals, articles, authors and editors.

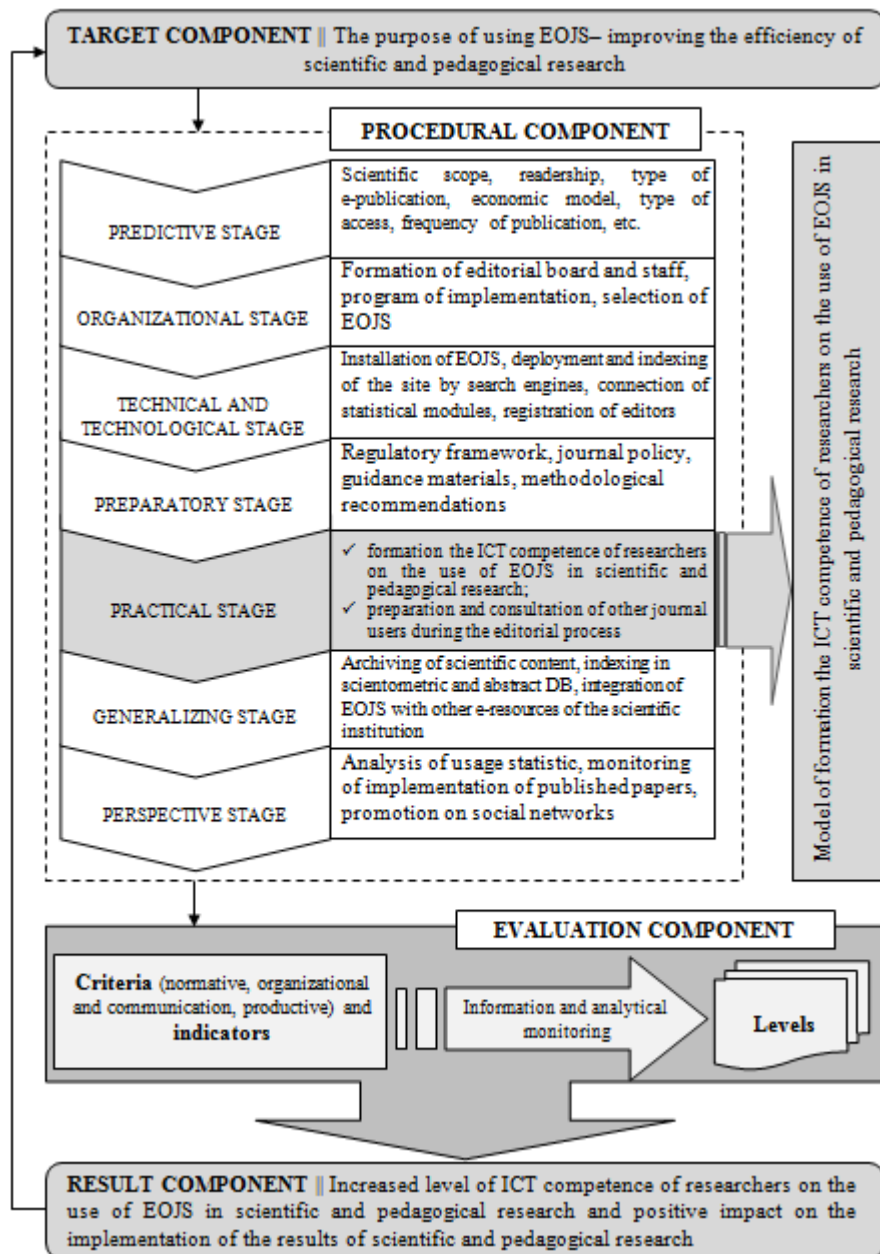


Fig. 1. The organizational and pedagogical model of EOJS use in scientific and pedagogical researches

2.3 ICT competence of researchers on the use of EOJS

ICT competence of researchers on the use of EOJS is the proven ability of a person to use such systems to solve professional problems in the process of scientific and pedagogical research, implementation and information and analytical monitoring of their results, as well as scientific communication and cooperation with colleagues based on acquired knowledge, skills and competences with the EOJS (Fig. 2).

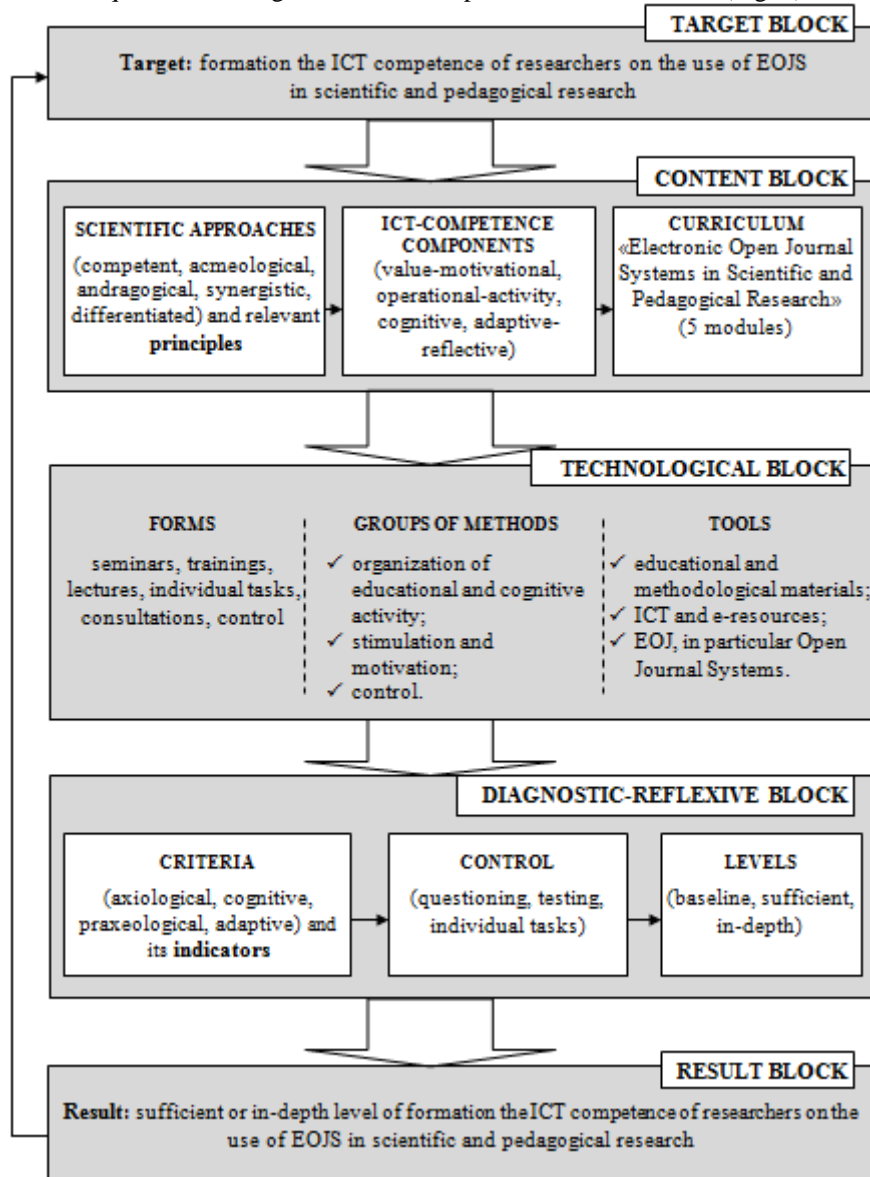


Fig. 2. Model of formation the ICT competence of researchers on the use of EOJS in scientific and pedagogical research

To characterize the ICT-competence of scientists we refer to the DigComp 2.0 - the Conceptual Reference Model, which identifies 5 key competence areas (information and data literacy; communication and collaboration; digital content creation; safety; problem solving). In the same time we take into account the professional needs of the scientists while using the EOJS for the professional needs. The following components are defined:

- *Value-motivational component*: motivation, value attitudes, awareness of digital technologies and its environmental impact.
- *Cognitive component*: the system of knowledge about devices, creation and editing of digital content, personal data and privacy in digital environments.
- *Operational-activity component*: skills and experience of communication and collaboration through digital technologies, creation, location, storage, retrieving, managing and organisation digital data, information and digital content.
- *Adaptive-reflective component*: adaptation, interaction, resolving problem situations in digital environments, usage digital tools to innovate processes and products, being keep up-to-date with the digital evolution.

According to these components we propose to distinguish the following criteria and indicators for assessing the ICT competency of researchers for the use of EOJS (Table 2).

Table 2. Criteria and indicators for assessing the ICT competency of researchers for the use of electronic open journal systems

Criteria	Indicators
Axiological	Striving for self-development and professional self-improvement. Awareness of the need for the use of the EOJS in the professional activity of a scientist. Interest in obtaining current and additional information on the possibilities of using the EOJS in the process of scientific research. Systematic use of the EOJS for finding and presenting research results. Willingness to carry out an impartial review of scientific works using EOJS. Striving to follow the ethical principles of academic virtue.
Cognitive	Knowing the content of the basic concepts regarding the use of the EOJS in scientific and pedagogical research. Awareness of current electronic means of formal and informal scientific communication and modern ICT for supporting the process of presenting the results of scientific and pedagogical research. Knowledge about international standards of educational research ethics and ethics of presenting the results of scientific and pedagogical researches. Awareness of the importance of peer review in the development of science and the benefits of the role of "reviewer" for the scientist.
Praxeological	Ability to search and analyze quality scientific content. Ability to select the best electronic means of disseminating research results in the international scientific and information space. Ability to carry out all stages of the editorial and publishing process using EOJS. Ability to use specialized software tools to prepare the manuscript for printing. Ability to conduct research and publishing ethical standards. Ability to review scientific manuscripts by EOJS. Ability to use open information and analytical systems.

Rapid response to the emergence of new ICTs to support the process of presenting scientific and pedagogical research results.
 Ability to creativity, criticality and initiative in working with the EOJS.
 Ability to enhance the knowledge, skills and experience of working with the EOJS functionality at higher levels of user access.

3 Research Methods

The experimental work was carried out during (2010–2018) and consisted of the following stages:

1. Preparatory stage (2010–2014):

- study of scientific and technical documentation, national legislative framework and international normative documents of using electronic open journal systems in scientific and pedagogical research; identification the components of ICT competence of researchers for the use of electronic open journal systems; clarification the criteria, indicators, and levels of its formation; designing appropriate model and method; implementation of Open Journal Systems for the deployment of a prototype of a scientific e-journal "Information Technologies and Learning Tools" (<https://journal.iitta.gov.ua>).

2. Experimental stage (2012–2016):

- 2012: 161 participants (132 researchers, 6 administrators, 14 editors of scientific journals, 9 ICT staff) were interviewed about the sources and means of search and publication the results of scientific research in their professional activity.
- 2015–2016: the training was held to develop the ICT competency of researchers on the use of EOJS in scientific and pedagogical research (146 participants). The experimental group (EG) consisted of researchers who were trained under the author's curriculum [35] (69 researchers). The control group (CG) consisted of researchers who were able to use the developed educational, methodological and instructional materials in their activities, attend seminars provided by the Institute of Information Technologies and Learning Tools, and obtain knowledge independently from different sources (77 researchers). The experimental influence on this group of researches wasn't carried out.

Diagnostic the level of development of ICT competence of researchers for the use of electronic open journal systems was carried out by input and output evaluation of the levels of its formation (basic, sufficient and in-depth). The questionnaires and description of the evaluation procedure are presented in author's dissertation (<https://lib.iitta.gov.ua/716976/>, Section 4, Appendixes R, S, T).

3. Interpretation stage (2017–2018):

- collecting and processing empirical data using methods of mathematical statistics, comparing the obtained results with the hypothesis of the study;
- conducting the information and analytical monitoring of the scientific journals of the NAES of Ukraine (see the questionnaire here: <https://cutt.ly/tuP41Ya>).

4 Findings

4.1 The ascertaining stage of the experiment

As a result of a survey at this stage of the experiment (2012), it was found that researchers typically use journals, monographs, and collections of conference papers, paper-based review literature, e-presentations at conferences, e-mailing, as well as visit research libraries. Bibliographic literature, preprints, scientific e-publications, scientific e-journals and e-monographs, postprints as well as online conferences, electronic scientific repositories, official websites of academic institutions, online video, discussions on Skype and YouTube podcasts are somewhat less used. The data banks, peer-to-peer correspondence, webinars, messenger chats, blogs, scientists' websites, e-portfolios, scientometrics, and abstract databases, Wiki technologies, electronic science forums and social networks are almost unused.

63% of researchers prefer a paper format for presenting their research results. The majority of respondents (72%) are aware of the benefits of publishing research results in scientific e-journals, while at the same time they are partially (38%) aware of the existence of the EOJS to support scientific e-journals. Only a small percentage of scientists (23%) have experience of using EOJS in the process of research: to find the necessary scientific data (33%), to publish their scientific articles (29%), to review the of colleagues papers as reviewer (24%), as editor of the scientific periodical (12%). There was an insufficient level of interest in the use of scientific e-journals based on electronic open journal systems (34%).

In the process of ascertaining stage of the survey it was succeeded to find out the absence of a general strategy for the transferring the scientific journals into EOJS for support the editorial and publishing process; adequate logistical facilities (servers, personal computers), IT-specialists and sufficient funding for the deployment and functioning of the EOJS at each academic institution. There is a lack of manuals on the use of the EOJS, in particular, the in Ukrainian; psychological and technological unpreparedness of researchers to publish their scientific papers and use the means of electronic open journal systems for editor and reviewer tasks; educational and methodological materials (instructions, methodological recommendations, etc.) for the development of ICT competence of researchers; the absence of training the scientists of the National Academy of Educational Sciences of Ukraine, in particular regarding the ways of presenting scientific results.

4.2 The formation of researchers' ICT competence

The results made it possible to conclude that at the beginning of the experiment the level of researchers' competence was lower than the baseline level in both the CG and the EG, and upon completion of the study it changed to the baseline level in the CG and in-depth level in the EG (Fig. 3). In particular, the *value-motivational* component in CG increased to the baseline level (40%), in EG increased to a sufficient level (71%); the *cognitive* component in CG reached a sufficient level (62%), in EG – in-depth (83%); *operational-activity* component in CG increased to a sufficient level (54%), in EG – to in-depth (92%); the *adaptive-reflective* component in the CG reached the baseline level (33%), and in the EG – reached the sufficient level (62%).

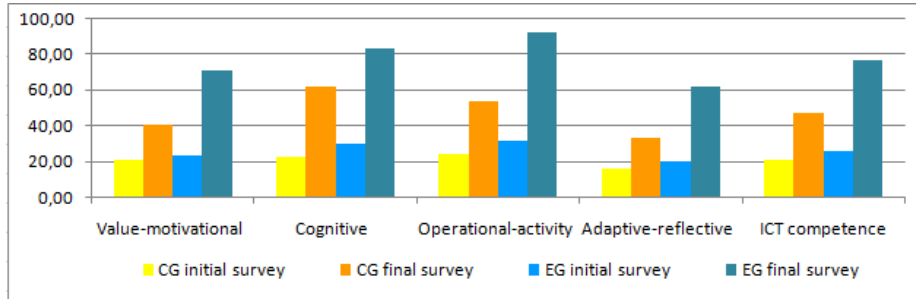


Fig. 3. Diagram of ICT competence levels of CG and EG of researchers at the beginning and end of the experiment

Fisher's angular transformation method was chosen to confirm the validity of the study results. This multifunctional criterion is intended to compare two groups of subjects by the frequency of the surveyed effect occurrence and to assess the shift of effect values. We have taken into account all restrictions on its use [44, p 158].

The following statistical hypotheses were tested:

- H_0 – at the beginning of the experiment EG-scientists have a level of ICT competence on the use of EOJS in scientific and pedagogical research no higher than CG-researchers.
- H_1 – at the end of the experiment, the researchers who were experimentally influenced by the author's methodology (EG) have a higher level of ICT competence on the use of EOJS in scientific and pedagogical research than the researchers from the CG.

The value of the angle was determined (in radians):

φ_1 (26,05%) = 1,070, where φ_1 – the angle that corresponds to the results in the EG before the experiment.

φ_2 (21,05%) = 0,952, where φ_2 – the angle that corresponds to the results in the CG before the experiment.

$$\varphi_{emp}^* = (\varphi_1 - \varphi_2) \sqrt{\frac{n_1 \cdot n_2}{n_1 + n_2}} = (1,070 - 0,952) \sqrt{\frac{69 \cdot 77}{69 + 77}} = 0,118 \cdot 6,032 = 0,71,$$

where n_1 – number of participants of EG; n_2 – number of participants of CG.

The obtained empirical value of the angle is less than the critical values and does not fall within the area of significance. Conclusion: the hypothesis H_0 is confirmed – significant differences of indicators in the control and experimental groups at the beginning of the experiment are absent. (Fig. 4.).

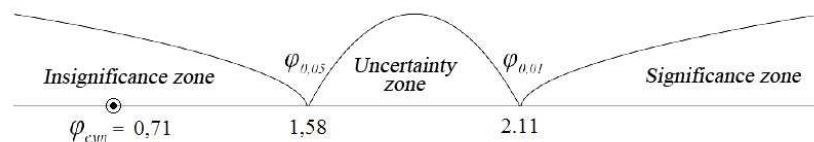


Fig. 4. Significance axis of statistical validity of results by Fisher's angular transformation at the beginning of the experiment

The value of the angle was determined (in radians):

φ_1 (76,84%) = 2,127, where φ_1 – the angle that corresponds to the results in the EG after the experiment.

φ_2 (47,28%) = 1,515, where φ_2 – the angle that corresponds to the results in the CG after the experiment.

$$\varphi_{emp}^* = (\varphi_1 - \varphi_2) \sqrt{\frac{n_1 \cdot n_2}{n_1 + n_2}} = (2,127 - 1,515) \sqrt{\frac{69 \cdot 77}{69 + 77}} = 0,612 \cdot 6,032 = 3,69$$

The obtained empirical value of the angle is greater than the critical values and falls within the area of significance. Conclusion: the hypothesis H1 is confirmed – significant differences of indicators in the control and experimental groups at the end of the experiment are present (Fig. 5.).

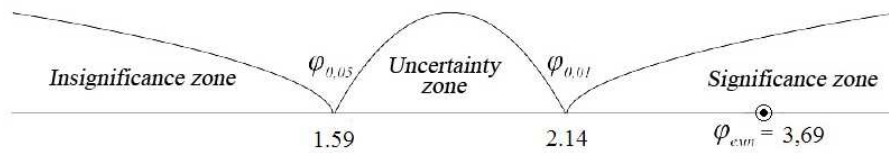


Fig. 5. Significance axis of statistical validity of results by Fisher's angular transformation at the end of the experiment

The results of the experiment confirmed that the proposed author' method of EOJS use in scientific and pedagogical studies increases the level of researchers appropriate ICT competence.

4.3 Information and analytical monitoring of the scientific journals of the National Academy of Educational Sciences of Ukraine

During 2017–2018 the information and analytical monitoring of the scientific journals of the NAES of Ukraine which operate based on the OJS was carried out in the following areas: a) observation of the editorial and publishing activities of scientific journals; b) comparing their sites usage statistics (the number of registered users in each year and the variety of their geographical distribution; the number of site views); c) analysis of their publishing performance (number of published issues per year; the number of published articles per year); d) comparison of scientometric indices of journals, articles, authors and editors (h-index by Google Scholar; Top 10 most cited journal articles by citation; h-index of the authors of the most cited article; h-index of the editorial board members).

It should be noted that 100% of the data on functioning were obtained only on the electronic scientific journal "Information Technologies and Learning Tools", the activity of which was carried out by the author's method. The statistical modules of other editions were either missing or partially connected. Finally, the editors being unable to respond to all survey questions. Comparisons were made for scientific

journals where certain quantitative indicators could be extracted from the site. Some of the monitoring results are presented in Fig. 6–11.

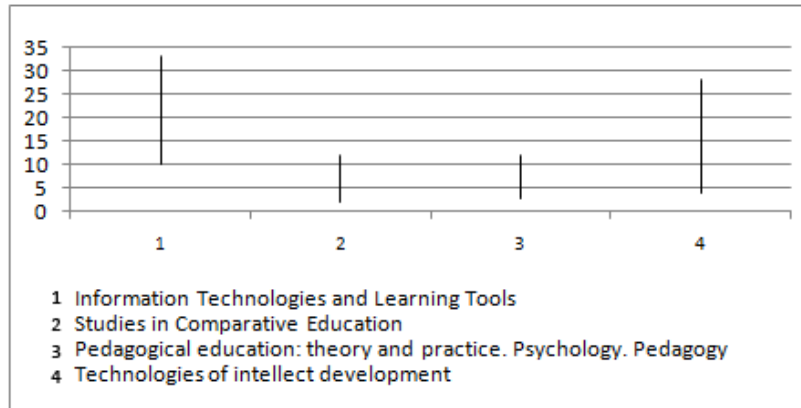


Fig. 6. The h-indexes of the editorial board members of scientific journals

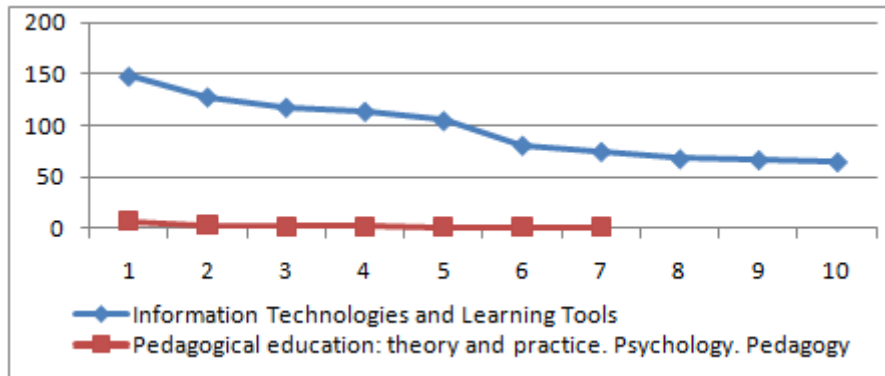


Fig. 7. Top 10 of the most cited journal articles by citation

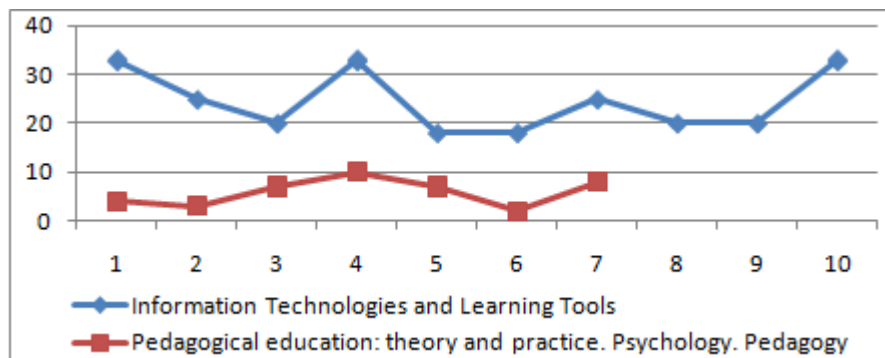


Fig. 8. The h-indexes of the authors of the most cited articles

The following diagrams demonstrate the number of published issues per year (Fig.9.), the number of published articles per year (Fig. 10.) and the number of registered users per year (Fig.11.).

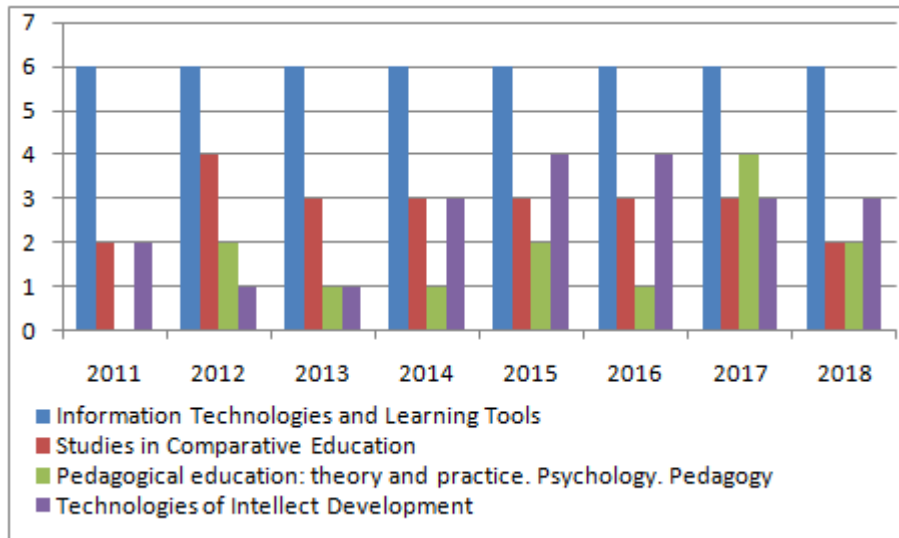


Fig. 9. The number of published issues per year

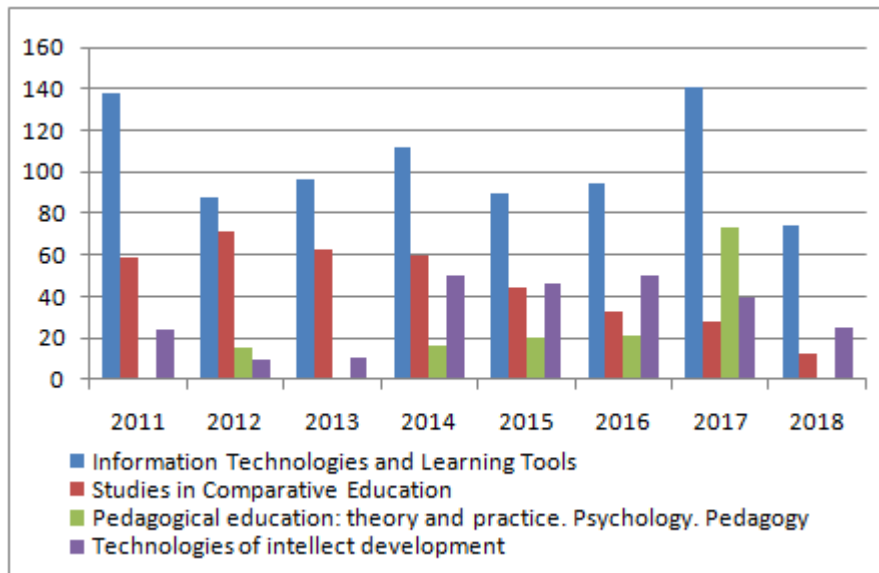


Fig. 10. The number of published articles per year

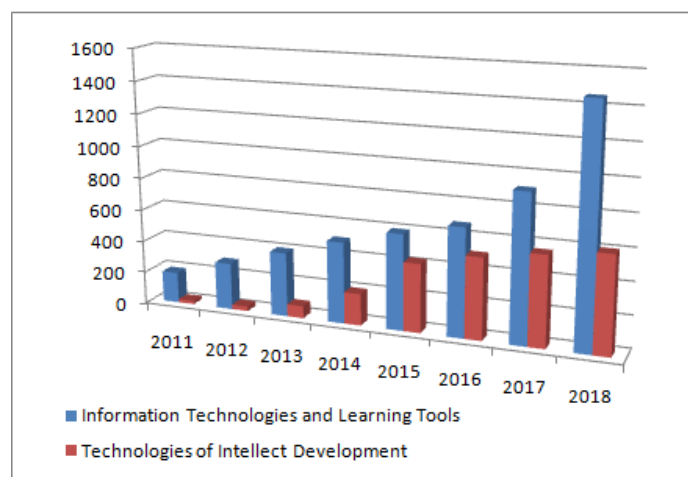


Fig. 11. The number of registered users per year

5 Conclusion

The results of the comparative analysis of initial and final data combined with the methods of mathematical statistics (Fisher angular transformation) confirmed the positive dynamics of the development of researchers' ICT competence in the use of EOJS. It allows us to conclude on the positive impact and effectiveness of the author's method.

As a result of the information-analytical monitoring, a positive difference in the values of scientometric indicators of articles, authors and editors of the experimental journal was found, in comparison with the indicators of other editions of the National Academy of Educational Sciences of Ukraine.

The results of this research can serve for the deployment and supporting the electronic journals of scientific institutions and institutions of higher education, as well as for teaching the scientific and pedagogical workers, postgraduate and doctoral students, masters and bachelors.

The further research should be done in the sphere of teachers in service training to develop their ICT competency on the use of EOJS.

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Formation of Personalized Learning Path for Foreign Students Based on the MOODLE E-Learning Platform Using SCORM-Package

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Abstract. In the paper questions about using Distance Learning Platform based on the SCORM standard for definition structure of teaching materials and creation personalized learning path for students are discussed. The authors made research of teaching way of the discipline Information Technologies for foreign students on the basis distance learning platform. A proposed strategy must take into consideration national, language, psychology and cognitive features of students, different their skill levels not only from information disciplines but also from other general science subjects.

A number of reasons conditions the relevance and practicability of the study. First, learning of foreign students in the maritime academy requires the creation of according conditions for them, which help better adapt to the learning process. Second, scientifically planned and methodically determined distance learning can help to students to be not cut off educating when they have practice training in remote areas.

Efficient use of education distance form depends on a built learning management system (LMS) and information technologies by which it had been realized.

Application of SCORM-package improves cognitive orientation, its accessibility, variability, creative education aspects and contributes to forming a public usable web-based learning environment. SCORM-packages have been developed taking into account a standard, so can be used for e-learning system based on different platforms.

Without taking into account that involved training course of marine professional was oriented to foreign students, the research results can be applied for students' teaching in other areas, because usage of SCORM standard allows to develop learning course independently of a software platform and some topics are general for the forming of information culture of trainees.

Keywords: Learning Management System, SCORM-packages, Distance Learning Platform, Information technologies.

1 The general problem statement and its actuality

The term “e-learning” means any education with information technologies. Electronic learning has greatly impacted to education in general, making it available to anyone interested student, who wants to obtain deeper knowledge in various areas. Educational institutions at all levels use learning management systems as an essential part of the organization today. This enables students all needed materials of each course, which is part of the training program for a relevant field. Certainly, methodological content must be quality and satisfy of the educational program.

But there are some specializations for which e-learning usage is not only desirable but indispensable element for learners preparing. These included qualifications related to work at sea, when student can't attend classes because long time is not just abroad, but far away in the sea or ocean. However, career of the marine specialist, destiny or even lives of the crew and ship sometimes depend on sailor's knowledge, skills and attitudes, physical and moral training. To date, the primary problem of maritime education institutions is quality training of marine professionals, which can do complex problems and take right management decisions. So, the graduates' competitiveness in the international labour market depends on as far as full teaching institution applies modern technologies in education using all possible resources which defines actuality proposed material.

2 Analysis of recent research and publications, which launched the solution to this problem

In recent years, e-learning has received much attention including in publications – tutorials, articles, workshops. Besides, there is about applying of increased abilities of distance learning platform and their apps. The e-learning resources such as SCORM standard are particularly popular that allows the application of distributed processing technologies (cloud educational service) besides to the direct function exchanging of training materials and management of the learning process. Both works of domestic and foreign authors have focused on this topic.

The paper by H. Husieva [1] has a detailed description of Learning Management System in the SCORM format. This is where author discusses the full cycle of establishing a training unit based on interaction SCORM-package and LMS in the structural form (apps for administration, documentation, path tracking and other online activities). Authors Yu. Telnov and O. Rohozyn [2] have devoted their work to preferences of educational objects that were created in SCORM standard and have built own develop based on SCORM. Their conducted experiment has shown the effectiveness of using develop when courses are created and, most importantly, improving the quality of teaching students.

Analysis of possible use of DLS content in the SCORM format is executed in the papers of L. Zamikhovsky and V. Yakubovsky [3], O. Baibuz and N. Kharchenko [4]. On the other hand, many scientific works focused on the optimal choice of training resource, which allows to create personalized learning path of a learner taking account

his education attainment and personal preference. For instance, P. Brusilovsky [5] much attention has devoted to create an appropriate learning path of students. The same view is shared by K. Limonhelli [6] and T. Lendiuk [7], who are active supporters of creating a personalized learning path for each student in order to achieve target knowledge level. Greek scientists P. Karampiperis, D. Sampson [8] consider the definition of learning resource sequence as learning path. International scientific community, for example, P. Libbrecht [9], E. Bowling [10], has long been involved about the problem of reusing e-learning, hence there are some international standards in this direction that describe can be found and in the papers M. Hlybovets [11].

The works of N. Valko, N. Osipova, N. Kushnir [12] are devoted to the characteristics of STEM technologies and the description of the pedagogical experience of using interactive teaching methods in higher education.

3 Solving basic problems

Most of the educational institutes are used course management system Moodle (Modular Object-Oriented Dynamic Learning Environment). Each teacher decides for self in what format own course will be created, how teaching materials structured for students' interest and involving them to general process of mutual understanding, which arouses desire to learn and self-learn. The user's attitude to the chosen educational system largely depends on educational institution's attitude to current technologies, its provision of modern technologies, means of communication and general strategy of introducing distance forms of providing knowledge in educational process. Additionally, the strategy itself depends on specifics of educational institution and the student body. But far not all users to the full possess features of work with resources and objects Moodle – LMS's with open source codes. Obviously, this system provides what's necessary for distance learning. It contains blocks for direct course creation, in addition, with applying of interactive elements, providing feedback, communication both between students and teacher, and between students themselves, testing the learners' level of mastering.

But capabilities of distance learning system can be greatly enhanced by downloading course elements, which are SCORM-compliant and can be displayed in a web browser.

The purpose of this article is an analysis of developing process of structure and content distance teaching material and formation personalized learning path in an environment of DLS using SCORM package. This approach should take into account psychological, personal and cognitive characteristics of learners.

SCORM standard has proved successful in foreign institutions and is actively used in the learning portals of Ukrainian educational establishes. It defines structure of learning materials and interface, so all learning objects can be used in different e-learning systems. Besides, SCORM standard is provided management of educational process and applying of selected parts of learning material without significant change its structure.

LMS Moodle several years is one of the educational process elements of Kherson State Maritime Academy (KSMA) not only as a modern training tool of theoretical and practical materials, but also checking learners' quality of education. In fact, it is a very

convenient learning platform, but not enough when it comes to foreign student education.

International relations in education are great importance for Ukraine higher education institutions. Firstly, it is exchange of experience, scientific and pedagogical ideas and views on the modern educational space. Secondly, it is a real opportunity not only to see how are learning in other countries, but also to involve students in this process. However, some Ukraine institutions in can compete with similar overseas universities. The citizens of different nations from Asia, Africa and Europe (Bangladesh, Cameroon, Lebanon, Ghana, Egypt, etc.) had desire to be trained in KSMA after carefully studied training level and educational environment there. In fact, its material and technical base meets the highest standards and contains such training complexes, which other maritime educational institutions would envy.

A multinational group of foreign students, each of whom communicates in English with an appropriate dialect, requires a special approach. This is about adaptive learning approach that takes into account both the mentality of each student of such groups and their different levels of prior training, and, most importantly, the training specific at a maritime institution that trains marine professionals for international campaigns. Thus, teachers should not only have professional competencies and sufficient communication skills in English for teaching but also correctly organize work of English-speaking group.

Let's show what problems teachers have faced, who conduct classes in foreign student groups and what methods of decision these problems they offer.

We'll do it on the example of discipline "Information Technologies" our department in KSMA and modern training methods based on the technical possibilities of the institution, teacher's experience and creative teaching approach.

From 2016 onwards, that's four years in a row, the Academy accepts foreign students, who wish to be marine education. Not only in each academic year but even in each group, students are different from each other by nationality, level of English, which causes some teaching difficulty in such groups. We would like to stress separately two main points. First, it is a dialect and some slang expressions that foreign students use when communicating both with each other and with the teacher. Very often it makes difficult for understanding and translate the students' speech during class. Second, it's a training level. With the example of discipline Information Technology that is taught the first year at the academy, we are dealing with a polar different computeracy level in foreign student groups. Therefore, in our opinion based on own experience, the issue of adaptive learning in such groups is most relevant, so, requires the introduction of modern forms and methods of teaching. The teacher's task is to plan classes in such a way as to make work in a group effective, interesting for students, as much as possible, taking into account all their features, capabilities and experience.

A personalized approach in education was implemented by our department with DLS of KSMA built on the Moodle platform. Resources and activities of Moodle allowed to create training courses such that each student could choose his or her own learning path, get complete information on this or other department's discipline, perform and send practical works to the teacher for checking and be tested for assessing the level of material mastering.

During the first two academic years, distance learning courses were developed that have used interactive elements of Moodle. Availability of multimedia equipment in classrooms, student's ability to work on PC, his (or her) access to the course's electronic resources significantly improved the learning quality. But a thorough analysis of the Moodle platform operating principles allowed to add modules that were created in the SCORM format in training courses. This standard provides compatibility of course components, presents training material in separate blocks, greatly enhances the possibility of learning personalization and student's independence in the learning.

Taking into account teaching experience in foreign student groups, it can be noted that the creation of SCORM-packages and their use in classes of the discipline Information Technologies is very effective in the learning. First of all, the teacher forms the structure of the future package, which should cover all information elements, training, consulting, the performance of planned practical works, checking knowledge, etc.

In the academic year 2018/19, the usage of SCORM-package for foreign student group was first proposed. The student is able "to travel" independently on educational material through the properly designed course structure thus increasing cognitive motivation and knowledge levelling. The survey results showed that work with such resource is much more convenient for student.

Experience of the above-mentioned academic year has helped to expand possibilities SCORM-standard guided by basic principles of package designing, namely:

- Quantization principle that is a distribution of material into modules, which have minimum amount but closed in content.
- Completeness principle (each module has following components: theoretical core, questions on theory, examples, tasks and exercises to solve independently, questions on the module, test, context help (Help), comments).
- Visibility principle: the availability of a visualization that makes possible to understand and memory of new concepts, assertion and methods.
- Branching principle: each module should be hyperlinked to other modules so that user has choice of switching to another module. It ensures to the student be able choose the personalized learning path.
- Principle of regulatory and adaptability: student manages module's blocks independently by selecting the level of complexity, study sequence, applied orientation that depends on the learning purpose.
- Principle of computer support: the learner can get computer support for performing standard actions at any moment of the topic processing to focus on the main material; it should be noted that student must be proficient in the computation techniques of a sufficient level of complexity.
- Collection principle: that is, all module's elements are made in formats, which provide to collect it's into electronic complexes, to expand and supplement in new blocks.

These principles have formed the basis of the course Information Technologies for foreign students. For example, structure one of the interactive course's modules Information Technologies was designed based on SCORM methodology in the application iSpring Suite 9.0 on the topic "Tabulation of the function and graphing in MS EXCEL".

Note that this topic is very important for any student of technical higher education, because it not only reveals topic, but also generally covers such elements as an understanding of analytical dependence (formulas), knowledge of Excel's built-in functions, ability to perform calculations in accordance with a mathematical model.

Teacher offers a standard lesson structure for this course to systematize student's work and choosing own learning path (see Fig. 1). But the student can control time independently that spent at any stage, and most importantly, can review any step, for example, theoretical material or explanations for practical tasks, without leaving the SCORM-package. Additionally, the student can learn the topic even if he or she was absent from class for certain reasons at any convenient time.

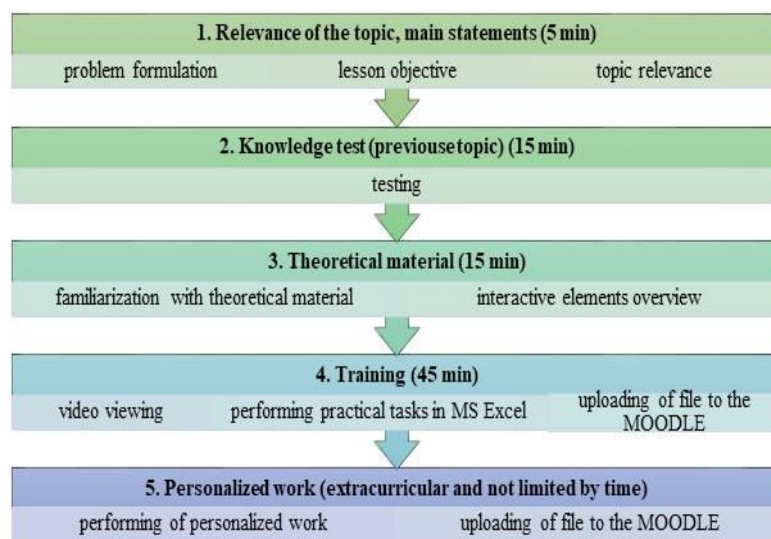


Fig. 1. Lesson structure with SCORM-package

The next stage is a fill content of the created structure. The student's training level and interest to topic mastering dependence exactly on content quality. Therefore, teacher expands the learning material with interactive elements such as Video, Labeled Graphic, Media Catalog and others.

So, the package element *Labeled Graphic* was used when teaching the topic "Tabulation of functions and charting in MS EXCEL" (see Fig. 2). This element contributes to enhancing foreign students' understanding of the properties of excel chart components. Each label is responsible for a certain chart element. The student can see description of element clicking on the label. If necessary, he or she can refer to a theoretical description of the material or to the example of tasks execution, or while performing a personal task without leaving the package.

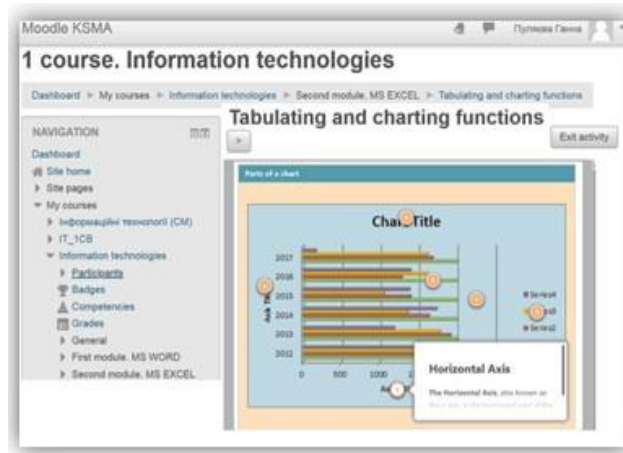


Fig. 2. Interactive element Labeled Graphic

One more interesting element of the package is "Tabs" that use when topic "Tabulation of functions and charting in MS EXCEL" teaching to familiarize with the basic kinds of charts. The student sees view corresponding type of the chart and its description pressing on the tab (see Fig. 3).

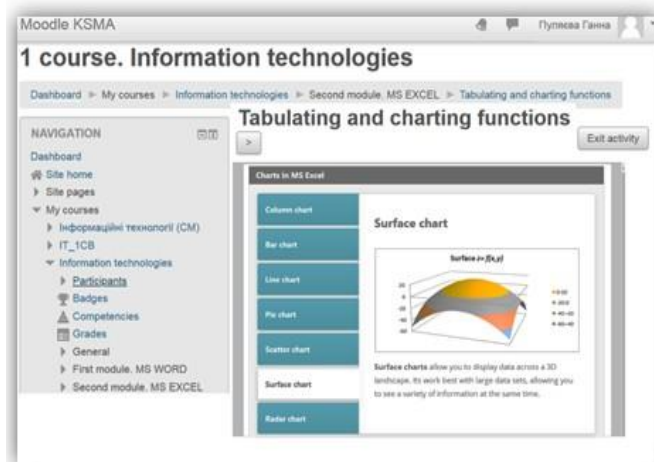


Fig. 3. Interactive element Tabs

Levels of relevant competencies formation in control and experimental groups have been analysed to confirm the hypothesis that modern training courses should provide an opportunity to build personalized learning path and e-learning courses that developed according to the SCORM standard is an effective tool for this.

The students' training results on discipline Information Technology in the academic years 2017/18 and 2018/19 have been taken by measures of a control group, the experimental group was formed in the academic years 2019/20.

The application of most statistical methods is based on the idea of using a random set of students, who took part in the study, from all persons on whom the conclusions can be spread, but in our case - all 100% of foreign first-year students were involved owing to the real learning process when we conducted experiment.

The level of formed subject competencies of foreign students has become an object of research and analysis.

A quantitative type of data variation was used to obtain objective data: discrete variation - students' total scores on topics were assessed, continuous variation - students' average points of current scores on each separate topic [13].

Percentage distribution of control and experimental groups' learners with different educational levels shows in the following chart (see Fig. 4).

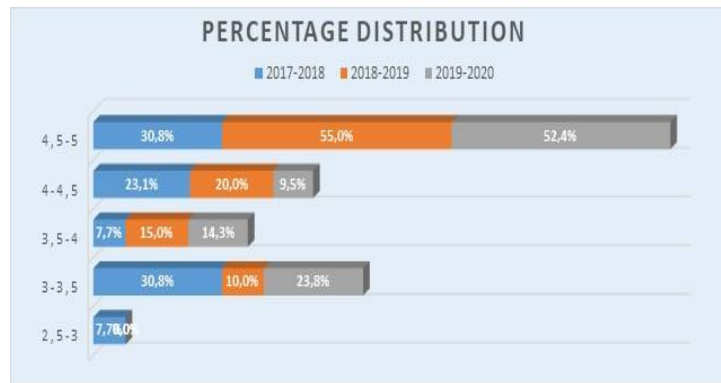


Fig. 4. Percentage distribution of control and experimental groups' learners

The variation series and histograms (see Fig. 5, Fig.6) of experimental and control groups by the average and total scores were constructed (Table 1).

Table 1. The variation series of experimental and control groups

Scores (W)	50	60	64	74	83	90	100	Σ
Number of control group students (f_{contr})	1	5	7	4	2	2	4	25
Number of experimental group students (f_{exp})	0	4	4	5	3	3	6	25

Measures of variation were calculated to extensive and full characterization of variation facilities. One of them is a weighted average:

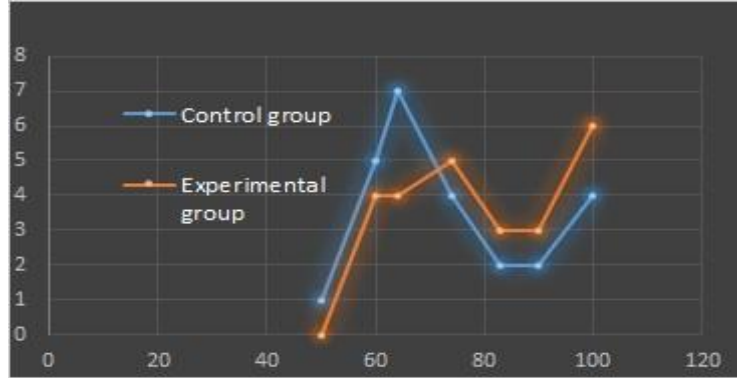


Fig. 5. Variation curves

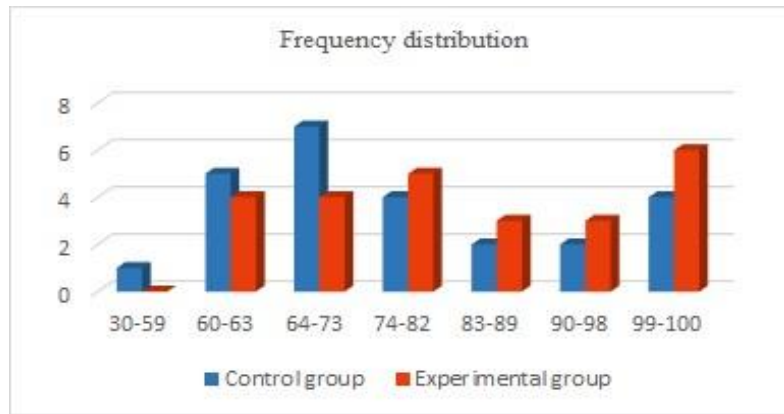


Fig. 6. Frequency distribution

$$M = \sum \frac{f_i \cdot W_i}{n}, \quad (1)$$

where n is number of all variants.

The average value of variation will be closer to values that occur more frequently. Therefore, closer to this value, first of all, we should hope to obtain most values in future observations.

We have obtained result for the control group: $M_{contr}=3.86$.

This value is equal: $M_{exp}=4.18$ for the experimental group.

This number is a specific centre of frequency dispersion observed values of an investigated quantity.

The average value does not fully characterize a series, because different in nature variation series may have the same average value. Therefore, essential distribution characteristics are also frequency dispersion characteristics, in particular the standard deviation (σ) of the observed values of the investigated quantity from arithmetic mean and dispersion (D or σ^2) a measure of variation. These values indicate the deviation of

a random variable from the distribution center and related to each other (dispersion is equal to standard deviation arisen to square) [14].

In our experiment, we have obtained the following dispersion values:

$$\sigma = \sqrt{\frac{\sum_{i=1}^n (X_i - M)^2}{n-1}} \quad (2)$$

$$\sigma^2_{\text{contr}}=0.067$$

$$\sigma^2_{\text{exp}}=0.056$$

Let hypothesis H_0 argues that level formation of foreign students' subject competencies when using SCORM packages on the distance learning platform does not exceed efficiency of the traditional teaching method discipline Information Technology. We shall accept an opposite assertion as hypothesis H_1 to hypothesis H_0 .

In other words, we will check the hypothesis that estimates' samples of the control and experimental groups belong to the same general population using the Kolmogorov-Smirnov test (K-S test) [15].

Let us calculate the value of K-S test to hypothesis testing

$$T_{\text{exp}} = \frac{1}{n} \max(\sum f_2 - \sum f_1) = 0.2, \quad (3)$$

where $\sum f_i$ is the frequency accumulation in relevant samples.

$$T_{\text{contr}} = \alpha \cdot \sqrt{\frac{n_1 + n_2}{n_1 \cdot n_2}} = 0,014, \quad (4)$$

where significance level $\alpha = 0.05$.

Since, $T_{\text{exp}} > T_{\text{contr}}$ so the alternative hypothesis H_1 was accepted over the null hypothesis H_0 in accordance with decision-making rule for the two-tailed test of Kolmogorov-Smirnov.

On the basis of statistical data, the conclusion was made: with probability 0.95 it can be considered as data of two samples belong to different general populations, i.e. experimental and traditional teaching methods of discipline Information Technologies provide different distributions of the learners' scores.

The results indicated to state the positive impact of SCORM-package implementation on training quality of future sailors and continue strategy formation, which would increase level of students' competence upon completion of the course.

4 Conclusions and directions for further research

Even though that specific training course for marine specialists oriented to foreign students is considered there, some topics are common for disciplines related to information

technologies in other areas of training. Applying of SCORM standard provides an opportunity to develop a distance learning course, which independent of the software platform on which the training will take place.

The problem of reusing electronic learning resources and their transferability from one virtual learning environment to another is always relevant for educational technologies.

In the future, we plan to develop a course based on the Learning Tools Interoperability (LTI) standard, which allows users of one environment to access resources of another. It makes possible to integrate them in United Distributed Learning Environment, which is created and shared [16]. For example, educational institutions may use publicly available e-learning resources that have been developed by other scholars, a uniform learning environment can be built on the institution, combining different platforms.

These focus on professionally directed disciplines such as Theory of Ship Structure, Navigation and Location, Ship Management and others in the field of training of maritime professionals. But the quality of specialist training is determined in all areas, including the skills of modern innovative technology. Additionally, the proposed teaching method to the disciplines of our department ITCSN is easy to introduce to other departments. Therefore, we consider the conducted study is timely, useful and practically applicable.

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The Key Features of the CoCalc Cloud Service Use in the Process of Mathematics and Science Teachers Training

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Abstract. The article describes the features of the evolution of the cloud-based systems in the context of mathematics and science teachers training. The notion of the systems of computer mathematics (SCM) is considered as the special kind of learning software. The lists of the special mathematical operations, functions and methods used within the structure of modern SCM are examined. Web-SCM properties are considered as general and specific. The cloud-based SCM are taken as the special stage of Web-SCM development. The criteria for an appropriate cloud service selection to support the process of mathematics disciplines learning are revealed. The key features of the CoCalc cloud service use are considered in concern to the proposed selection criteria: the available computing capacities, the diversity of tools for training and its control, the possibility of increasing the computing capability, the openness of the program code, the availability of tools for joint editing. The results of the experimental testing of CoCalc use in the process of mathematics teachers training are described. Besides, the discussion covering the issues of integration and compatibility with the other tools and services used for mathematics learning (on the example of Octave) is presented. The main trends of the CoCalc cloud service introduction into the training process and the prospects for further research are revealed.

Keywords: CoCalc, teacher training, science and mathematics subjects, science teachers, Octave.

1 The problem Statement

There is a need to develop new learning technologies and models of educational environment design for qualified teaching staff training, [8]. This problem can be solved using cloud technology tools. The main advantage of implementing cloud computing is the openness of access to qualitative learning resources (sometimes providing the only possible way to access the necessary resources). The idea is to identify the approaches and to assess the methods for implementing the learning components in the cloud in the process of mathematics teachers training.

The study aims to outline the state of the art and the current progress in the sphere of the cloud-based systems of computer mathematics development, to reveal the key features of the structure and functions of the cloud service CoCalc, relevant for its application as a tool for learning mathematics disciplines and to evaluate the promising trends of its application in the process of mathematics and science teachers training.

1.1 The Analysis of the Current Research

E. C. Granado, E. D. Garcia [1] have shown in their study that the Jupyter Notebook offers a rich content environment that facilitates learning while integrating the simulations performed in Python. In this way, the student learns numerically as he/she learns the concepts explained in the lesson.

The components of the author's educational mobile environment elaborated by M. A. Kislova are the following:

- the tools for organizing educational processes and mathematical calculations,
- the mobile tools to support the communication of a group of listeners,
- the tools to support the process of teaching higher mathematics and personal interaction between students and teachers [3].

Except just mobile learning the researchers have been paying much attention to the use of cloud services for learning. For example, M. A. Kislova, K. I. Slovak [2] analyzed several cloud services used in combination with the usual, traditional teaching aids in the learning process such as: Office 365, Google Apps for Education, ThinkFree Online, the advantages of these tools application for teaching mathematical disciplines were highlighted.

Substantial achievements in terms of research opportunities of the cloud technologies use in education were made by the following scientists: G. A. Aleksanyan, V. Yu. Bykov, M. Yu. Kademiya, V. M. Kobysya, O. G. Kuzminskaya, V. M. Kukharenko, S. G. Lytvynova, N. V. Morse, V. S. Mkrtchyan, A. S. Sviridenko, Z. S. Seydametova, S. O. Semerikov, O. M. Spirin, L. V. Rozhdestvenskaya, Y. V. Trius, M. P. Shyshkina, B. B. Yarmakhov, M. I. Zhaldak, and others. These issues were also investigated by M. Armbrust, R. Griffith, Y. Khmelevsky, M. Miller, K. Subramanian, N. Sultan, W. Chang, P. Thomas, A. Fox, et al.

The use of the cloud services has a number of advantages (according to N. V. Rashevskaya) [6]:

- data will be available from any device with the access to the Internet;
- working with all educational materials without installing third-party software;
- the opportunity to study anywhere and anytime (outside the classroom);
- the possibility of using blended and distance learning.

There is a separate group of research studies devoted to the problems of cloud technologies use for teachers training. Among them, there are the works of T. L. Arkhipova, N. V. Bakhmat, T. V. Zaitseva, Yu. G. Lotyuk, N. V. Soroko, M. A. Shynenko et al.

The use of the Sage computer algebra system for learning mathematics was studied by P. Zimmermann, A. Casamayou, N. Cohen, G. Connan, T. Dumont, L. Fousse, F. Maltey, M. Meulien, M. Mezzarobba, C. Pernet, N. M Thiery, E. Bray, J. Cremona, M. Forets, A. Ghitza, H. Thomas [9]. The researchers were exploring the functionality of symbolic computing systems, giving examples of the use of separate commands to solve common mathematical problems.

In the study of A. B. Liecharlie [4], the CoCalc cloud service was used to process a large array of data.

M. D. Ruiz and F. Torralbo [7] investigated the advantages and disadvantages of using the CoCalc cloud service in training. The authors have described the platform, the methodological system and the peculiarities of teaching in the context of different modes of use of the cloud service. Some methods of teaching different subjects using CoCalc were exposed.

As there are new facilities and modes of using the cloud services in education due to the latest achievements and developments in this area, in particular, the current progress of CoCalc applications, the issues of innovative use of this kind of services need further attention. Among them, there are issues of the search for the new forms, methods and possible models of CoCalc use in the process of training mathematics teachers to support the teaching of mathematical disciplines.

2 The Main Results of the Study

2.1 The Main Features of Modern SCM Composition

The modern SCM can be of different types, application areas and architecture; still, they appear to have similar key features of their structure and composition [2]. They include usually the next main components:

- one of the main components is the computing core of the system;
- standard default codes for use in complex user functions and procedures;
- intuitive user interface that will allow you to perform quickly complex calculations using a standard set of functions;
- powerful graphics packages that may be used in mathematics and other areas;
- packages of additional modules that significantly expand the capabilities of SCM;
- additional modules, libraries and functions that are not included by default in the kernel;
- flexible help system that simplifies the use of certain functions, libraries, templates.

SCM provides strong support for the study of mathematical disciplines:

- the ability to open parentheses in expressions containing characters;
- the calculations of the values of numerical expressions;
- the use of symbolic values of variables to calculate a symbolic expression;
- to simplify expressions, including the opening of parentheses;
- finding the exact and approximate roots of equations or systems of equations;
- performing a number of tasks in mathematical analysis;

- construction of graphs of functions and surfaces, images of vectors on the plane and in space;
- a number of functions to perform tasks of linear algebra and others.

2.2 The Evolution of the Cloud-Based Systems of Computer Mathematics

In the process of SCM evolution the special kind of them such as Web-SCM emerged along with their gradual transformation into cloud-based systems. In recent years, the cloud-based versions of mathematical packages from major providers, such as Maple Net, MATLAB web-server, WebMathematica and others have been supplied. A variation of this type of systems is CoCalc, the cloud-based version of Web-SCM Sage.

SCM has undergone some changes over time. During the 60's and 90's of the XX century SCM were mostly local, ie required installation on a local computer.

In the 90s of the XX century and until the first decade of the XXI century, Web-SCM appeared, which allows you to work with SCM directly via the Internet and configure a web browser. It was the second stage of SCM evolution. The main features of such SCM are:

- the computing core does not require pre-installation on the user's device;
- all calculations take place on the web server (user standby capacities may be low);
- all calculations can be organized using a web browser.
- Web-SCM also has specific functions:
 - does not depend on the technical characteristics of the user's personal device;
 - you can use any browser;
 - intuitive ease of introduction;
 - constant access to educational materials anywhere and anytime, etc.

The most commonly used are Web-SCMs such as MapleNet, MathCAD Application Server (MAS), webMathematica, Matlab Web Server (MWS), Sage and wxMaxima. Web-SCM has an intuitive interface, powerful graphics packages for building and visualizing mathematical objects, functions and methods.

Specific characteristics of modern SCM are:

- the use of the elements of mathematical functions and programming languages;
- integration with other software;
- the capability of editing and printing of mathematical texts.

The use of Web-SCM had certain advantages: the availability of powerful tools for building and researching mathematical models for various mathematical disciplines.

The first version of SAGE emerged in 2006. The first cloud systems were developed in 2009, it caused the third stage in the development of SCM. CoCalc (new name) is a cloud service that combines all the features and tools of SAGE and Web-SCM SAGE.

2.3 The Criteria for Cloud Services Selection

The following selection criteria may be used for selecting a cloud service, appropriate for the certain educational needs:

- computing power provided for the work of an individual user, as well as how much data may be processed simultaneously;
- whether there are tools for organizing and monitoring the learning process (for certain disciplines, setting different levels of learning tasks, reviewing the process of implementation and evaluation of learning results, both for groups of users and individual students);
- availability of different tariff plans to expand the computing capabilities of the cloud service (availability of additional functions);
- open source code and free access to the installation or integration of additional modules and applications (including author's tools) along with the basic set of tools being protected;
- availability of tools for creating, storing, joint editing of resources or files in various formats (the most common and compatible with modern devices).

2.4 The Comparison of SageMathCloud and CoCalc

Sage is a software that implements mathematical algorithms in different contexts. To begin with, it can be used as a scientific pocket calculator and can manipulate all sorts of numbers, from integer and rational numbers to numerical approximations of real and complex numbers with arbitrary precision. However, mathematical calculations go far beyond numbers: Sage is a system of computer algebra; for example, it can be used to support solving linear equations or search for solutions, simplify expressions. In the process of analysis, Sage can manipulate by the expressions relating to square roots, exponents, logarithms, or trigonometric functions: integration, calculating limits, simplifying sums, series, solving certain differential equations, and more. In linear algebra operations with vectors, matrices, and subspaces can be performed. It can also help illustrate individual tasks in probability theory, statistics, and combinatorics [9].

Sage service will provide the user with consistent access to functions across a wide area of mathematics - from group theory to numerical analysis, and further to two- and three-dimensional visualization, animation, networking, databases. Using all the necessary functions within the unified cloud service is convenient for a user who doesn't transfer data between multiple tools and learn the syntax of several programming languages.

The specifics of using CoCalc is primarily the capability of projects creation (both group and individual) and uploading training materials to them. After that users will be able to share them. There is a chronology of user actions with individual training material and with the project as a whole. These features are useful in the process of evaluating each user individually.

CoCalc is the online computing environment [1] that provides several unique tools of learning use: it enables Jupyter Notebook file sharing, which empowers group work

and supports the course and task manager, which simplifies the teacher's task of supplying support material, assigning task solving and providing comments and grades for students. It is also free of charge and therefore students have access to the materials at the end of the course, which occupies modelling and explanations that may be useful in other subjects of the following courses. It also has paid packages that offer access to more stable servers with more computer resources.

The freeware software that is installed is much diversified, covers many programming languages, and can be easily expanded by installing other programs on Linux in user space. CoCalc user personal space is organized into different projects, each with its files that can be generated on the platform or downloaded from a user's computer. On the other hand, it also has tutorials on different aspects of both platform use and programming in different languages. Regarding the course management, the teacher can add students by their email address, assign tasks, automatically form a specific folder for all course participants, keep track of the edits to these assignments, and return a corrected copy to all students with the one click of a button. Another useful feature of CoCalc as for a teacher point of view is that it allows simultaneous editing of Jupyter Notebook documents in the Google Documents style, thanks to the proprietary version of the Jupyter Notebook web interface. This add-on, not included in the default Jupyter notepad, greatly facilitates group work on the task and is complemented by integrated chat on the platform itself. All of these options make CoCalc a complete and easy-to-use solution for integrating Jupyter files into an academic course. Also, the openness of the code led to the emergence of a local version of the platform, which could be installed on any computer. This local version can be downloaded from the GitHub development page and, if the local computer is powerful enough, used for teaching a Jupyter Notebook course [1].

CoCalc (formerly called SageMathCloud) is a cloud computing and math calculations management platform. CoCalc directly supports the Sage worksheet, which interactively evaluates the Sage code. SageMath (formerly Sage or SAGE, an algebra and geometry system for numerical operations and research) is a computer algebra system that has various functions that cover many aspects of mathematics, including algebra, combinatorics, graph theory, numerical analysis, calculus, and statistics. The new name CoCalc, which stands for Collaborative Calculations, reflects the evolution of the conventional cloud computing and calculation platform. Spreadsheets in CoCalc support Markdown and HTML as design and R, Octave, Cython, Julia and others for programming other than Sage [4]. The main difference between CoCalc and SageMathCloud is that CoCalc is primarily focused on collaborating on any file in the system, editing and communicating during teamwork and organizing the students group learning process. While the main benefit of SageMathCloud was the use of the cloud computing approach. Almost every CoCalc file contains a built-in chat, participant group change history, and an easy (intuitive) feature to add new users to the project.

CoCalc is an open-source software provided by SageMath Inc. The creator and principal developer of CoCalc is William Stein, a professor of mathematics at Washington University who also created the Sage software system. The initial development of CoCalc was funded by Washington University and grants from the National Science Foundation and Google. At the moment, CoCalc is largely funded by paid users.

3 The Results of the Experimental Testing of the Use of CoCalc in the Educational Process

To test the effectiveness of using CoCalc as a tool for teaching mathematical disciplines for pre-service teachers of mathematics the pedagogical experiment was conducted in 2017, at the Pedagogical Institute of the Kryvyi Rig National University (Kryvyi Rig).

The experimental group and the control group were formed according to the following principle: in the experimental group there were students who studied the author's method of using CoCalc (EG), in the control group there were students who studied the traditional method (CG). The obtained results proved that the level of teachers' professional competencies formation in the experimental and control groups coincided with the level of significance $\alpha = 0.05$ before the formation stage [5].

Comparing the levels of professional competences formation in control and experimental groups it was possible to observe the increase of a share of students with average and high level of professional competence after the formation stage of the experiment.

Comparison of the distribution of the experimental and the control groups of students after the formation stage of the experiment (scale levels): high – from 16% to 20%, sufficient – from 26% to 36%, average – from 27% to 28%, low – from 31% to 16%. During the study only some components of subject, professional and practical and technological competencies have been compared at four levels (high, sufficient, medium and low), among them: subject-pedagogical, mathematical and information-technological competencies. According to Fisher's test, the data at the beginning of the experiment and at the end were compared.

The analysis of the results of the forming stage of the pedagogical experiment showed that the distribution of the levels of the formation of professional competencies in the experimental and control groups of mathematics trainee teachers has statistically significant differences due to the implementation of the developed method of using the cloud service CoCalc, which confirms the hypothesis of the study [5].

During the various teaching experiences, several shortcomings of the cloud service use were identified. The first disadvantage is the inability to prepare self-assessment questionnaires (simulators, tests). This tool, available on many training platforms such as Moodle, is not currently available on CoCalc. This tool would allow a teacher to learn the level of theoretical content knowledge of a student on a subject before the practical tasks. However, the CoCalc extension is planned [7], that will allow the teacher to evaluate the exercises by developing tests automatically. The second drawback concerns only in the free tariff plan, which limits the calculating of large amounts of data, or the installation of additional libraries if necessary for a specific task. However, in the process of teachers training, the high computation and accuracy process maybe not so important. An alternative that addresses this second drawback is the purchase of a paid tariff plan from CoCalc. Another option is to install and maintain a Jupyter server using JupyterHub software [7], in which the SageMath character system should be installed as a Jupyter kernel. The second option will allow you to perform intensive calculations (according to server performance), as well as the possibility to install the Jupyter Nbgrader extension [7], to implement a form of self-assessment for programming tasks. One more option, if the agency has a contract with Google, is to use Google

Colaboratory, which allows to implement Jupyter and share an interface similar to Google Drive.

The third limitation that was found concerns to the assessment of group work, since there is no option to create or evaluate activities for a group of users in a whole, which also allows you to evaluate the participation of each small group within it.

4 Discussion

There is a way to examine the difference between working with software in local-based and cloud-based versions comparing the use of different programming tools of CoCalc cloud service (by the example of Octave).

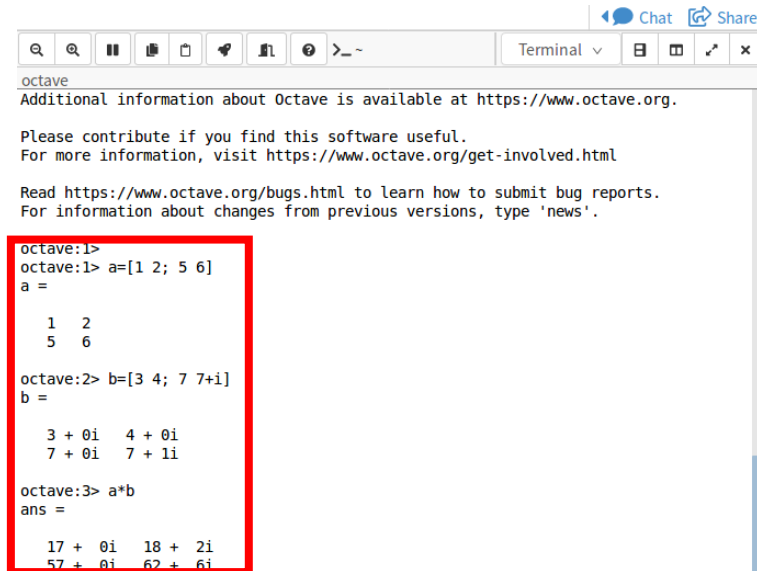
Octave is available in CoCalc along with other kinds of languages such as Python, Java, C, and so on. Octave is an interpreted language designed for mathematical computing, it is largely compatible with MathLab. This is the reason that this tool is becoming more and more popular and useful in the process of math teachers training. In particular, in the Taras Shevchenko National University of Kyiv (Ukraine) there is a separate laboratory course devoted to it.

The use of Octave based on CoCalc enables the user to work with Octave in a cloud and also to use it in collaboration. Sagemath may provide the mathematical functions (for working with matrices, vectors, graphs, mathematical constants, equations), but the syntax may be different and not compatible with MathLab. The source code for Octave is freely distributable under the terms of the GNU General Public License (GPL) it makes possible to use free all of its functions in the learning process.

In the cloud version, there are the same commands as in the local one (Fig. 1), and also there are some additional possibilities. There are tools for easy collaboration such as video chat, chat commands, code history of each user, the ability to save files (Fig. 2).

The advantage of the cloud version is that it can be accessed from different computers, even from a smartphone.

The cloud-based interface of Octave used through CoCalc may slightly differ from its local version, though not very significant, as its capabilities remain. When you create a file with the extension .m, you open an editor where you can edit the text, you can cut, copy, paste, there is a search in the text. The '> _Shell' key lets you run the code. The 'file' key enables you to work with the file (Fig.3).



```
octave
Additional information about Octave is available at https://www.octave.org.

Please contribute if you find this software useful.
For more information, visit https://www.octave.org/get-involved.html

Read https://www.octave.org/bugs.html to learn how to submit bug reports.
For information about changes from previous versions, type 'news'.

octave:1>
octave:1> a=[1 2; 5 6]
a =

    1    2
    5    6

octave:2> b=[3 4; 7 7+1i]
b =

    3 + 0i    4 + 0i
    7 + 0i    7 + 1i

octave:3> a*b
ans =

    17 + 0i    18 + 2i
    57 + 0i    62 + 6i
```

Fig. 1. The Octave code is running in the terminal



```
File Save TimeTravel [Control Keys] Shell Print
2020-01-14-190715.m
1 a=[1:10]
```

Fig. 2. Open editor and control keys

There are different ways to work with Octave in CoCalc. You can simply create a file with the extension `.m`, then you can open the terminal and run the file in it.

The `.term` file is used to use Linux terminal commands. In the terminal, you can run Octave or create a file with extension `.m` or `.x11`.

In the file with extension `.x11` you can run different applications. There is possible to open Libre OfficeWriter, the environment for Python and so on and also use Octave as in the local version.

Now the Octave language is penetrating the math teachers' education process. This language is a useful tool for teachers training as it enables learners to perform different mathematical calculations and operate with functions. Comparison of using the local version of Octave and the cloud one (based on CoCalc) is a prospective trend for further research.

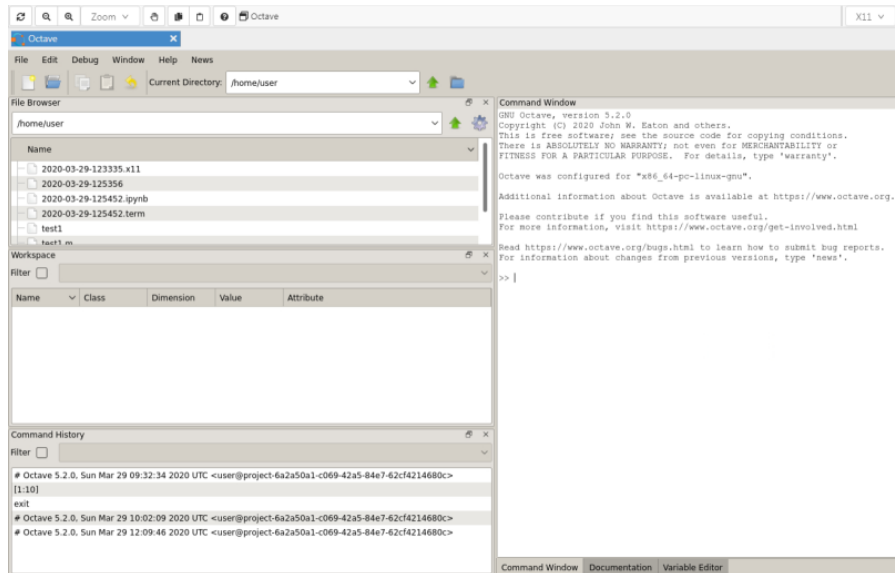


Fig. 3. Octave Editor: general view

5 Conclusions

The emergence and development of new forms of learning, focused on the collaboration of groups of students and joint activities in the online mode was caused by the availability of cloud services (including specialized). It is justified that the cloud services may be purposely used in the process of science and mathematics teachers training as tools for:

- group communication of listeners (synchronous and asynchronous);
- collaboration in real time;
- processing, systematization and storage of educational data.

Among the areas of CoCalc use in the science and math teachers training process are the next:

- organization of communication during the educational process;
- support of various forms of educational process (individual and group) both classroom and extracurricular;
- support for the organization of training;
- visualization of interpretations of mathematical models, mathematical abstractions by visualization;
- providing open access using a common interface and reliable software;
- increasing mobility in time and space;
- compatibility with other types of mathematical software, as well as the possibility of cloud access to various software packages, including Octave based on CoCalc;

- formation of the learning environment and filling its content during the learning process.

The described teaching experience with the use of CoCalc demonstrates its potential to become a ground for a variety of learning methods.

The teacher, through the use of the control and monitoring tools offered by the system, can supply and control students performance that is an added benefit of using this platform. Finally, this service is also suitable for use as the research collaborative platform.

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Distance Learning Technologies in Institution of Higher Education by Means of LCMS Moodle

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Abstract. Distance learning (DL) is one of the most rapidly expanding sectors in higher education today. Distance Learning Development requires a consistent solution to a number of important tasks in the field of regulatory, organizational, educational, technical, software and staffing, the interaction of all these elements of the DL system in the implementation of educational programs. One of the most important tasks in organizing distance learning is to define a scalable and viable strategy for creating an information and communication environment. The article presents a review of distance learning literature; the purposes, advantages, disadvantages. The experience of Kherson State University in the use of distance learning was summarized. Particular attention is paid to the implementation features of the KSUONLINE distance learning system developed on the basis of LMS Moodle. The educational courses and webinars were designed to introduce teachers to the principles of creating Distance courses and learn how to ensure effective communication between teachers and students. The research of the level of satisfaction of teachers with seminars to study the capabilities of the distance learning system KSUONLINE was conducted. The main problems associated with the introduction of distance education in Institution of Higher Education are analyzed in this paper. The factors that influence the development of distance learning in universities are identified.

Keywords: Distance Learning, E-Learning, LCMS, Moodle, Technologies, Institution of Higher Education, Teacher Training.

1 Introduction

Distance learning refers to the individualized process of acquiring knowledge, abilities, skills and ways of cognitive activity of a person, occurs mainly through the indirect interaction of remote participants of the educational process in a specialized environment, functioning on the basis of modern psychological, pedagogical and information and communication technologies.

The legal framework for distance education in Ukraine was launched in 2000, when the "Concept for the Development of Distance Education in Ukraine" was approved. It envisaged the creation in the country of a system that would satisfy the needs of society

in the continuity of long life learning education and individualization of education. In Ukraine, there are a number of important laws and programs that regulate some issues of distance education: “On approval of the Program for the development of distance learning system for 2004-2006”, Order of the Ministry of Education and Science, Youth and Sports of Ukraine; “On approval of the Regulation on electronic educational resources”, Order of the Ministry of Education and Science of Ukraine; “On Approval of the Regulations on Distance Learning”; Approval of the sectoral concept of development of continuous pedagogical education. Order of the Ministry of Education and Science of Ukraine; CMU Resolution “On Approval of Licensing Terms of Educational Activity”.

The legal base of distance learning determines the behavior of the teacher in the distance learning process, provides preservation author's rights, outlines the duties of a tutor in the field of distance learning, normalizes work teachers in the field of distance learning, provides material incentives teachers to activities in the field of DL.

Ukraine has adopted a law on the Digital Agenda 2020, which outlines a strategy for non-formal education. Provision of state support for educational service providers is envisaged. It also points to the need to develop quality educational content, review and update training programs for training and training civil servants, educators and the unemployed, and the introduction of digital competencies. This can be a good basis for the development of distance education.

The state policy of Ukraine in the field of higher education, in accordance with the Law on Higher Education, is aimed at ensuring accessibility, quality and effectiveness of education. Various solutions are proposed, one of which is the informatization of education. In turn, informatization allows the effective development of such pedagogical technology as distance learning.

Distance learning has several advantages: to study at any place and at any time, independently determine the amount of information to be processed in a certain period, the ability to receive high-quality, relevant knowledge, training in several directions at the same time, or combination with work, etc.

Also, distance learning has several disadvantages: limited practical tasks and assessment of the student's independent work; limited feedback capabilities; problems of plagiarism and identification; support for motivation to successfully complete the online course.

The urgent problem is the use of distance learning technology in a modern Ukrainian university. The use of distance learning in higher education solves the problem of individualization, intensification and optimization of education, is the most logical and natural evolution of the traditional model of education. The main goal of introducing distance learning is to introduce new forms of learning into the educational process that correspond to the trends of global development and the formation of the information society. Many universities have launched distance learning platforms (most often Moodle). Currently, more than 70% of educational institutions use LMS Moodle. Most often, courses are used to support traditional learning or as blended learning.

An important issue is the quality of the courses and their relevance to the educational needs of the modern generation of students (Howe and Strauss, Tapscott, Prensky, Berk) [1].

2 Related Work

The first attempt to describe the structure of the distance education discipline was proposed by Holmberg (1985). He considers the evolution, principles and practices of distance education. His categorization system includes the following areas: 1. philosophy and theory of distance education; 2. distance students, their milieu, conditions, and study motivations; 3. subject matter presentation; 4. communication and interaction between students and their supporting organization (tutors, counsellors, administrators, other students); 5. administration and organization; 6. economics; 7. systems (comparative distance education, typologies, evaluation, etc.); and 8. history of distance education [2].

The relevance and importance of distance learning is evidenced by a large number of projects, including: European Distance and E-Learning Network – the smart network for the distance and e-learning community and a professional community for smart learning [3].

A huge number of scientific and practical conferences are held annually on various aspects of the introduction of e-learning and distance learning, in particular in higher education [4].

The main differences between “e-learning” and “distance learning” are location, interaction, intention. Although many scientists and practitioners of higher education consider these terms as synonymous, given the blurring of the boundaries between regular and distance education [5].

Scientific works of Ukrainian researchers V. Bykov, Yu. Bogachkov, I. Bulakh, V. Kukhareno, N. Morse, M. Savchenko, N. Sirotenko, E. Smirnova-Tribulskoi, A. Spivakovsky, P. Stefanenko, B. Shunevich, etc.[6] are devoted to organization of the educational process in distance learning in higher educational institutions.

The problems of preparation of teachers of universities for the introduction of secondary education are considered in the works [8-10].

Historical and pedagogical analysis of the problems of the formation and development of DL in Ukraine and beyond abroad showed that the world has gained positive experience in implementing systems distance learning (LMS). Despite the unstable socio-economic position, a system of Distance education arises and is developing intensively both in higher education and in corporate education [6].

3 Problem Setting

The analysis of current statistics shows that only a very limited number of enrolled students complete distance courses as most students drop out at initial stages. The reasons causing low motivation is:

- universities and employers of Ukraine do not recognize distance course certificates;
- the failure to complete many courses leads to a loss of guidance in training and the refusal of further courses;

- lack of live communication hinders the process of teaching courses. Experience with interacting with classmates, peer review increases the likelihood of completing the course.

Many universities are only developing procedures for recognizing the results of non-formal education, which can include the study of distance courses. Students are also unaware of this possibility. If will be appropriate procedures for recognizing the results of non-formal learning, the interest and relevance of distance courses can increase significantly. However, having a certificate does not guarantee an adequate level of knowledge. In addition, there are not enough courses with more difficulty. The bulk of the material is designed to be simple to reach more listeners. There are also far fewer technical courses that suggest specific types of practical work.

The legal support of distance education should be supported by normative documents, regulate the ownership of software and teaching aids, provide students with the right to use the material and technical base and include:

- the regulatory framework for the creation and functioning of a distance education system;
- a set of documents of the educational process that determine the content, level and quality of training of graduate students;
- a set of standards (requirements) of universities for the creation, certification and use of electronic educational materials;
- copyright protection of the creators of distance learning courses and computer training programs;
- receipt of final qualification documents;
- recognition of the results of mastering courses taught under licensed DL programs.

The purpose of the article is define a scalable and viable strategy for creating an information and communication environment that supports distance learning in Institution of Higher Education.

The tasks of the article:

- analyze of principles and practices of distance education, technological and methodological aspects of the use of distance learning in Institution of Higher Education;
- description of the experience of using LMS in Kherson State University;
- development of courses and webinars to improve the qualifications of university teachers in the field of distance learning;
- implementation of the KSUONLINE - Distance Learning Network of Kherson State University, as the learning management system in Institution of Higher Education.

4 Principles and Practices of Distance Education

In Kherson State University there is an extending experience in distance learning [6, 7, 11-15]. The experience of the staff of Kherson State University Research Institute of Information Technologies in implementation of scientific and technical work within the

framework of the government program «Information and communication technologies in education and science», according to the agreement № IT/583-2009 from 23.10.2009 presented in [7]. As the result a web-resource "Bank of electronic documents in distance learning of higher pedagogical education" was formed.

Kherson State University has extensive experience in creating and implementing distance learning, including the development, maintenance and implementation of distance learning systems and integrated learning environments:

- Kherson Virtual University Distance Learning System (KSU development) [20].
- KSUONLINE - Distance Learning System based on LMS Moodle [21].
- Web portal ECDL e-learning for higher education (ECDL).
- Integrated Distance Learning Environment "Fundamentals of Algorithmization and programming" (based on LMS Moodle).
- Web-Almir Distance Learning System (own development of KSU).
- Integrated environment study course "Analytical Geometry" (KSU development).
- Integrated environment for testing student of economics and mathematics standardized parts for higher education for the specialty 6.050100 "Banking" 6.050101 "Economic Theory" (based on LMS Moodle).

The university has Department of Support for Academic, Informational and Communicational Infrastructure performs, whose tasks are:

- Design and development of Web-sites for different educational areas using Open-source systems.
- Design, development and support of educational software.
- Participation in competitive projects of fundamental research in the fields of "Informatics" and "Information technology".
- Holding an anonymous voting by KSU Feedback service.
- Publication of courses in the distance learning systems "KSU Online" (Fig. 1), "Kherson virtual university".
- Installation and support of the educational software tools.
- Exhibition activity.
- Consultations of the University staff and students.

The Moodle system meets all the basic criteria for e-learning systems:

- functionality - the presence of a set of functions of different levels (forums, chats, analysis of the activity of students, management of courses and study groups, etc.);
- reliability - ease of administration and training management, ease of updating content based on existing templates, protecting users from external influences, and the like;
- stability - a high level of stability of the system relative to various modes of operation and user activity;
- cost - the system itself is free, the costs of its implementation, course development and maintenance are minimal;
- lack of restrictions on the number of licenses for students;

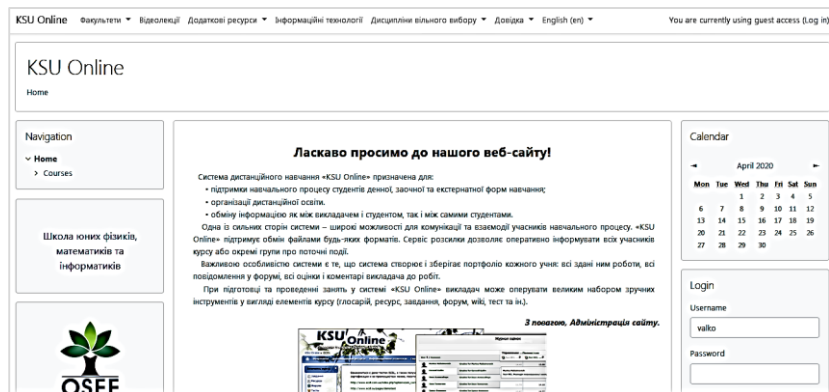


Fig.1. KSUONLINE - Distance Learning System of Kherson State University based Moodle, homepage

- modularity - the presence in training courses of a set of blocks of material that can be used in other courses;
- the presence of built-in tools for the development and editing of educational content, the integration of various educational materials for various purposes;
- support for the international standard SCORM (Sharable Content Object Reference Model) - the basis for the exchange of electronic courses, provides the transfer of resources to other systems;
- availability of a system for testing and evaluating students' knowledge on-line (tests, tasks, monitoring activity on forums);
- convenience and ease of use and navigation - an intuitive learning technology (the ability to easily find the help menu, ease of transition from one section to another, communication with a teacher-tutor, etc.) [22].

According to existing literatures [7], Moodle still comes out as the top used system among the open-source LMSs (Fig. 2).

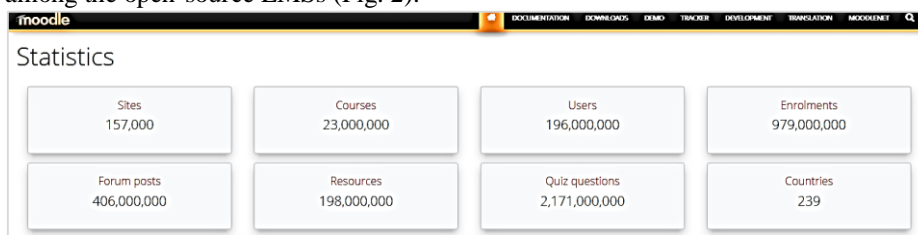


Fig.2. World statistics of LMS Moodle usage [16]

Moodle LMS has about 196 million registered users, 157 thousand educational portals, 23 million courses in 239 countries and unites more than 300 software developers.

The Moodle system implements the philosophy of "social constructionism pedagogy" and is focused primarily on organizing teacher-student interaction in the learning

process, although it can also be used to organize traditional distance courses as well as to support part-time and distance learning.

The design of the training course is to select effective tools used in the learning process to achieve the intended learning objective. There are two modifiers that influence the choice of tools that support the learning process:

- Personalization - implementation of individual educational trajectories.
- Involvement - embedding motivation mechanisms to reach the maximum number of trainees as planned.

In Kherson State University established "Regulations on distance learning at Kherson State University" [17]. The main provisions of this document are that these types of classes, such as self-employment, training, practical training, can be carried out in asynchronous mode. This will give impetus to the creation of courses that will support these types of classes.

From the year of foundation to the beginning of 2020, 409 courses were created on the platform KSUONLINE.

It is important to understand that the modern distance learning course is not just system of files with lectures, tasks, literature and tests which are loaded into the LMS.

According to the UNESCO Diversification of learning platforms [18] analytical note, the need to supplement LCMS functionality with web 2.0 services is emphasized. The support system for distance learning includes [19]:

- hardware (personal computers, network equipment, uninterruptible power supplies, servers, equipment for video conferencing, etc.) that ensure the development and use of web resources for educational purposes, educational process management and the necessary types of educational interaction between subjects of distance learning in synchronous and asynchronous modes;
- information and communication support with bandwidth of channels, which gives all subjects of distance learning round-the-clock access to web resources and web services for realization of educational process in synchronous and asynchronous modes;
- general-purpose and special-purpose software (including those with special needs) that must be licensed or built on open source software;
- Web-based resources of the courses (programs) required for distance learning may include:
 - methodological recommendations for their use, sequence of tasks, control features, etc;
 - planning documents for the educational process (curricula, thematic plans, classes);
 - multimedia lecture materials;
 - terminological dictionaries;
 - practical tasks with methodological recommendations for their implementation;
 - virtual laboratory work with methodological recommendations for their implementation;
 - virtual simulators with methodological recommendations for their use;

- packages of test tasks for carrying out control measures, testing with automated verification of results, testing with verification by a teacher;
- business games with methodological recommendations for their use;
- electronic libraries or links to them;
- bibliography;
- a distance course that integrates the above web-based resources of the course (program) into a single pedagogical scenario and other educational resources.

5 Experience in introducing distance courses at KSU

The topic of introducing distance learning is not new, There is a good world and domestic experience. In society there is an understanding of the importance and perspective of distance learning. The development of distance education at the university requires some resources, including specialists to administer distance learning platforms, but the main thing is the teachers who will develop distance courses and accompany the educational process. Analyzing the state of development of DL at KSU, it should be noted that the university has a system of regular seminars on the creation of training courses on each of the two distance learning platforms. The results of four advanced training courses for teachers of category 45+ in distance learning at Kherson State University are described in the publications [13-15]. A group of teachers has been formed, who have been actively using the capabilities of DL platforms, but the number of such teachers has been growing very slowly in recent years, because:

- creating a distance course takes a lot of time. The course materials are different from the materials used by the teacher in the regular classroom. And the preparation of such materials has been ongoing for a long time, through several iterative changes;
- an additional incentive system is required;
- the need for technical support;
- self-organization, the need for a sufficiently high level of student preparation for successful work in LMS;
- lack of collaborative work;
- obsolescence and lack of regulatory laws and lack of implementation practices;
- low teacher awareness of LMS courses creation and use;
- the courses created are often overflowing with copies of textual data, lack of clarity, formative assessment, group and teamwork;
- the primary reason for the unsuccessful courses is the lack of training for teachers to familiarize themselves with the LMS and create their components.

To date, the development of DL is taken into account in the Key Performance Indicators of the teacher. Quarantine has become a powerful external stimulus, which has actually forcibly transformed educational establishments of various levels into the format of DL.

A situation has arisen when teachers have started creating distance-learning courses en masse. Many technical questions were raised in the development process as teachers

had different levels of digital skills and different experience in using ICT in their professional activities. At the same time, people were in a situation of "alone on their own" with problems that arose. Against the background of the general psychological pressure, the need to quickly rebuild the style and mode of working with students, all this caused even greater difficulties. All teachers were sent emails via corporate mail with instructions for creating new distance courses and system administrators' emails were specify. Afterwards, we were invited to host a ZOOM webinar, which was attended by 93 people. After conducting the webinar, everyone who signed up was sent letters with a link to the video recording of the webinar, links to two courses "Workshop Tutor" and "Distance Education" (Fig. 3), again the addresses of system administrators, tasks-requirements for obtaining a certificate, links to surveys to evaluate the quality of the webinar.

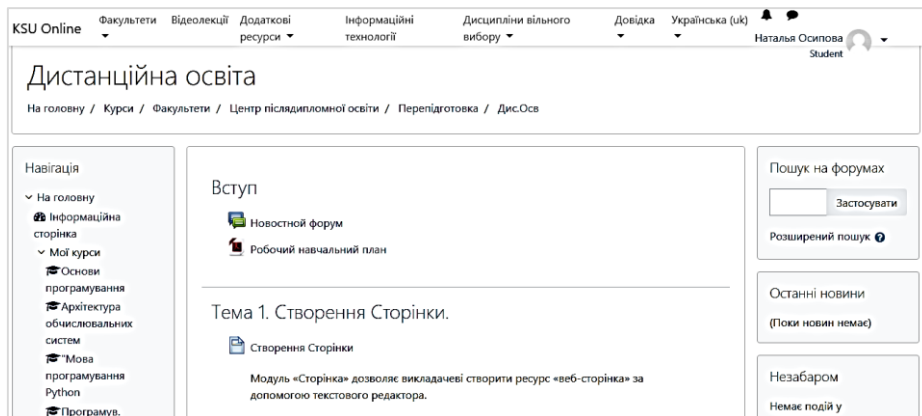


Fig.3. The course of “Distance Education” in system KSUONLINE

In general, the statistics of the training seminar were as follows: 93 teachers enrolled, 58 - participated in the webinar, 37 - developed courses and sent a link to the course to the organizers of the training seminar to check that the conditions for obtaining the certificate are fulfilled (Fig. 4).

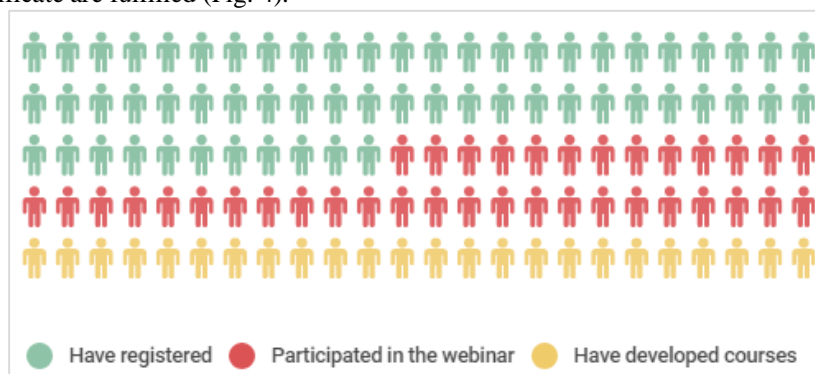


Fig.4. The statistics of the training seminar

After the seminars, statistics of DL-courses, which were created in the KSUONLINE, have changed significantly (Table1).

Table1. The statistics of the course developed

Faculties	Chairs	Number of courses for January 2020	Number of courses for April 2020
Faculty of Foreign Philology	5	34	218
Faculty of Economics and Management	5	33	171
Faculty of Culture and Arts	5	5	112
Historical and Legal Faculty	5	80	99
Pedagogical Faculty	4	29	88
Faculty of Ukrainian Philology and Journalism	4	31	64
Faculty of Biology, Geography and Ecology	4	6	8
Faculty of Computer Sciences, Physics and Mathematics	3	110	149
Faculty of Physical Education and Sport	3	0	128
Medical Faculty	3	39	115
Socio-psychological faculty	3	42	97
University departments	2	0	31

Examples of course titles developed from the results of a training seminar: "Sports specialization with teaching methods", "General linguistics ", "Anatomy and physiology of children and adolescents", "Modern Ukrainian literary language", "Genetics with the basics of breeding", "Tourist recreational complex of Ukraine", "History of Ukrainian Journalism", "Regional Economy".

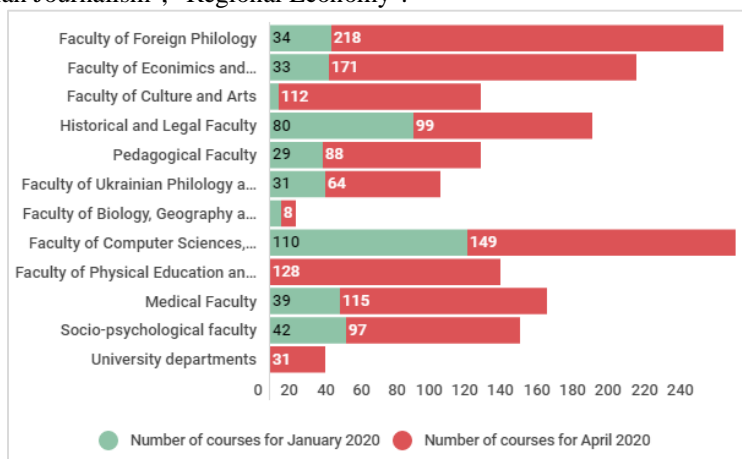


Fig. 5. The difference between the number of courses

It should be noted, that a greater increase in the number of courses occurred at the faculties: Faculty of Foreign Philology, Faculty of Economics and Management, Faculty of Physical Education and Sport (Fig. 5).

6 Conclusions and Outlook

The proposed strategy includes the evaluation of distance-learning training networks available in the Institution of Higher Education, as well as distance learning activities developed and implemented in order to ensure more effective achievement of learning goals.

Today the relevance of the topic of distance learning has gained new strength under the influence of external circumstances. Therefore, there was a need to revise the previous experience of distance learning, including the system of advanced training of teachers, to find fast effective forms of their counseling and training. Another important aspect is the creation of a system of motivational factors contributing to the development of distance learning including: the creation of a system of additional stimulation of teachers to create courses in the form of advanced training, rating system to evaluate the activities of the teacher, etc. It is advisable to introduce an internal system of certification of distance courses.

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Creation the Site-Quest by using the Cloud Services: From the Experience of Teaching Future Teachers

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Abstract. The paper highlights the author's experience of teaching future teachers the creation of a site-quest by using cloud services. Referring to the understanding of the concept of "web-quest", the explanation of "site-quest" is defined. The methodology of teaching future teachers about the creation of a site-quest by using cloud services is offered. Possible methods of their application for the organization of student work during the development of model and structure of the site-quest, didactic materials (mind maps, virtual boards, clouds of words, interactive exercises, etc.) and it is filling out are indicated. The experience of implementation of the described methodology on the example of creation by the future teachers of the site-quest "School of young programmers" in the lessons of the discipline "Cloud technologies in the educational process" is presented.

Keywords: site-quest; cloud services; creation of a site-quest; future teachers.

1 Introduction

Today's students will actively participate not only in consumption but also in the creation of information resources soon, regardless of their field of professional activity. Exactly they will become the driving force of the scientific and socio-economic development of society. Before the education of today became a problem of forming new-generation personalities who need to think analytically and act in a new way in times of uncertainty and crisis situations. In the system of training competitive specialists to come to the fore the qualities, such as: developed emotional intelligence and independence, high motivation and initiative, as well as the abilities to search and analyze information, to quickly learn and apply new knowledge, to create innovations, to self-master the necessary skills, to communicate effectively and collaborate as a team.

One of the ways of raising to a new level of quality of education is the use of pedagogues in the educational process of gaming technologies, which are implemented through information and communication technologies, in particular, cloud services. Their use allows to make the educational process both interesting and informative, promotes an increase of motivation, self-organization. This is achieved through the application of elements of gamification in the learning process, one of which is a web-quest. They make the lessons more effective, attractive and unforgettable for the students. As

a result, there is their comprehensive development, activation of cognitive interest, education of independence and responsibility for acquiring new knowledge. However, the development of cloud technologies and their implementation in education requires enhancing the ICT-competence of future teachers. This trend requires the modern teacher to have the ability to effectively use cloud services in the educational process. That is why, in this situation, the task to teach pedagogical students to design and create sites using web-quest technology or sites-quests is becoming increasingly important.

2 Analysis of Publications

Today the problem of the use of quests in the educational process is being actively studied by: B. Dodge, T. March, M. Andreeva, Y. Bykhovsky, O. Baguzina, O. Volkova, G. Vorobyov, O. Gapeev, M. Grinevich, L. Zhuk, L. Ivanova, N. Kononets, G. Shamatonova, O. Shulgin and others.

Recently, the use of the Internet for the implementation of modern technologies is impossible without the use of cloud services. Prospects for their active introduction into the educational space are highlighted in the scientific reconnaissances by V. Bykov, T. Vakalyuk, O. Gribyuk, O. Kuzminskaya, S. Litvinova, O. Merzlikina, N. Morse, Y. Nosenko, V. Oleksiuk, S. Seydametova, S. Seytvelieva, S. Semerikov, A. Stryuk, M. Shishkina, N. Khmil, and others.

Researches of Ukrainian and foreign scientists show considerable attention to the issues of web quest development using various services and web applications (O. Leshchynska, S. Ryabets and K. Gavrilenko (Google Blogger), L. Kozubay (One-Note), Y. Kornilov and I. Levin (through Platform of Interactive Storytelling and Text Games AXMA Story Maker) and others). The problem of training future professionals in the development and use of web-quests is exploring by M. Kademiya, N. Kononets, L. Savchenko, I. Sokol and others. However, N. Khmil draws attention to the fact that the scientific literature does not sufficiently cover the issues of theoretical and methodological substantiation of strategies, models of teaching future teachers the effective use of cloud technologies in the modern educational process [1, p. 105]. We believe that one of these strategies is to attract higher education students to create sites-quests with their help. This allows not only the use of cloud services as a means of training but also as a prerequisite for the formation of competencies in them for their use in future professional activity.

The purpose of the article is to describe the methodology for teaching future teachers to create a quest site using cloud services and to demonstrate relevant author's experience.

3 The theoretical basis of research

The formation of future teachers of general competencies is facilitated by the use of specially organized educational sites in the educational process. In the scientific-pedagogical literature, they are commonly referred to as web-quests.

The analysis of the essence of the concept of "web-quest" has led to the conclusion that the researchers (T. Bondarenko, M. Kademiya, E. Polat, N. Kononets, L. Savchenko, I. Sokol and others) understand its content differently. Common to all of the interpretations we consider is the availability of an online resource for organizing search activities during training. In the works of G. Moskalevich it is noted that "next to the term "web quest" is used the term "site-quest", which is interpreted as an online resource, which organized competitions for solving coherent and interconnected logical riddles" [2].

In our study, a quest site will be understood as an Internet resource presented in the form of a site on which certain situations are modeled for pupils (students) to carry out search activities to solve sequential and interconnected tasks.

Developing an educational web-quest is a creative process that depends on the skills and ideas of the author, as well as the choice of tools to create one. Analyzing the pedagogical literature and various examples of realized web-quests, it should be noted that cloud services are the most effective means of doing so. In our study, we will follow the definition of cloud services formulated by V. Bykov and M. Shishkina, who treat them "as services that provide the user with network access to a scalable and flexible organized pool of distributed physical or virtual resources delivered in a self-service and admin mode at his request (for example, software, storage space, computing power, etc.)" [3, p. 38].

In her research, N. Khmil emphasizes that cloud services used in the educational process can be "systematized by purpose and their pedagogical capabilities, namely: services for preserving and publishing didactic materials; services for visualization of educational information; services for creating interactive game exercises" [4]. This approach will allow us to demonstrate to future teachers a set of effective pedagogical scenarios for their use in the educational process when creating sites-quest.

4 Results of the Research

Consider the methodology of teaching future teachers to create a site-quest by using cloud services. It can be represented as a scheme (see Fig. 1).

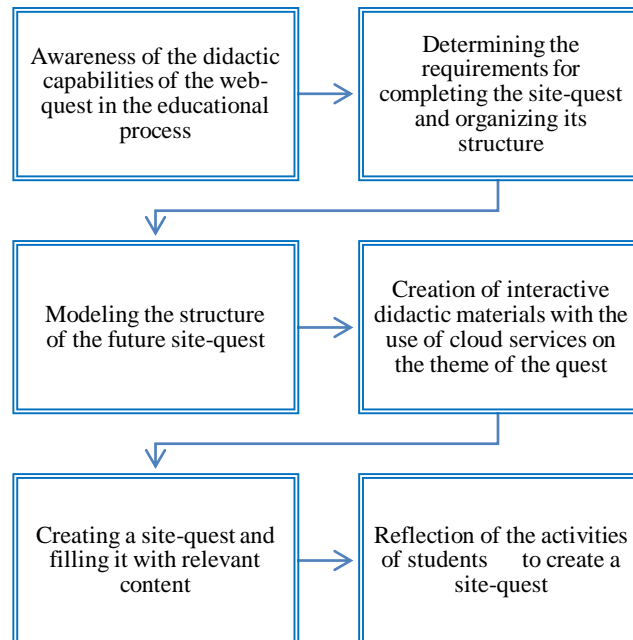


Fig. 1. The methodology of teaching future teachers about the creation of a site-quest using cloud services.

The first stage of "Awareness of didactic opportunities of web-quest in the educational process" involves acquaintance of students with web-quest technology; identification of its features and identification of its application in the educational process. To do this, it is appropriate for students to be offered to complete a web-quest in groups of 2-5 people. The selected or created site should meet the following requirements: availability of a task and a link for finding tips, a common table for showing the results of the tasks, the virtual board or any document for joint discussion of the results of the activity in the quest, etc. With the completion of the first stage, a scheme outlining the didactic capabilities of the web-quest for the educational process should be created in a joint document.

The second stage, "Determining the requirements for completing a site-quest and organizing its structure", involves discussing with students the structure and content of sites created using web-quest technology. To do this, you should invite them to analyze and evaluate in advance selected examples of sites-quest with a different methodology for organizing search and feedback. While working, students should state the purpose of creating the site; to consider and evaluate the task of the quest (to determine the purpose of the proposed task and the method/approach to its completion); evaluate the relevance of the content of the site to the theme of the quest and the quality of the proposed tasks for accessibility. The result of the second stage is to create quality assessment forms jointly in the Google Docs and Google Forms by indicating the identified criteria.

The purpose of *the third stage "Modeling the structure of the future site-quest"* is to create a model for students of the structure of the future site-quest, indicating the content of its filling. At this stage, it is necessary to familiarize students with the rules for finding information of various kinds, emphasizing the copyright of them when using the data found. It is important to focus the attention of future teachers on a common set of tasks, the definition of their presentation (text, picture-puzzle, interactive exercise, interactive video, etc.), and how they plan to organize the interaction of the participants of the quest. To build students' ability to create a site model, it is important to focus their attention on the fact that they must determine the list of objects that will be placed on it; determine their place and role, indicate possible or necessary transitions between them.

During the implementation of the third stage, students' activities should be directed to the joint fulfillment of the proposed tasks, in particular: to discuss and choose the theme and purpose of creating a future site-quest, to ensure joint storage of the found data - content (texts, audio, video, etc.), to determine the content, structure of the site and develop his model, work out the selected material. This approach makes it possible to understand the importance of working together in the process of creating a site-quest. The result of the students' activity should be a jointly created model of the future site-quest in the cloud service.

The fourth stage of *"Creating interactive didactic materials using the cloud services on the topic of the quest"* involves the systematization of students' knowledge of cloud services (services for creating clouds of words, infographics, interactive posters, interactive exercises, and online questionnaires, virtual interactive boards, etc.). To make students aware of the appropriateness of using a particular service, we pay attention to the didactic functions and practical tasks that they can accomplish. This approach allows them to form in them the skills of analyzing and defining the capabilities of cloud services, identify indicators of their functionality and security, to outline the purpose. In the next step, students are encouraged to design and develop electronic didactic materials to meet information security requirements by using cloud services.

The implementation of *the fifth stage of "Creating a site-quest and filling it with relevant content"* involves the formation of skills for future teachers to jointly develop a map of the site-quest and filling its pages with relevant content. Students' activities should be directed to joint interaction in the process of posting pre-created electronic didactic materials on the site pages. It is appropriate to organize a presentation of student site-quests with further self-evaluation and mutual evaluation of their quality.

For the future teachers to understand the importance of understanding the process of creating a site-quest for its further use in student learning, it is advisable to organize *the final stage "Reflection of student activity on the creation of a site-quest"*. It is aimed at developing students' ability and ability to evaluate completed actions, to analyze the process of mental activity during the creation of a site-quest.

Our methodology was tested in the process of teaching future elementary school teachers in the course "Cloud technologies in the educational process" during the study of the following topics: "Web-quest in the educational process", "Technology for developing web-based quests using cloud services" and "Creating a site-quest structure and filling it with content".

In the lesson on the first topic, we have implemented the first two stages of the proposed methodology. To become aware of the didactic capabilities of the web-quest in the educational process, future teachers were encouraged to complete the quest "The Secure Internet" (<https://cutt.ly/htWLzjA>). For this purpose, a special site was created that met the above in the first stage requirements. After completing the joint paper, they have drawn up an appropriate list of didactic opportunities web-quests.

Further, students were encouraged to familiarize themselves with other examples of quests that were created by future teachers studying at other higher education pedagogical institutions (<https://cutt.ly/7tWLCGK>, <https://cutt.ly/ntWLvV7>, <https://cutt.ly/mtWLB3k>), and by teacher-practitioners (<https://mediainpact.at.ua/publ/>, http://webquest_artificial_intell.tilda.ws/, <https://cutt.ly/AtWLYrT>). As a task, they were asked to evaluate the quality of the submitted text and formulated tasks to perform, the ability to represent the results of the quest, the clarity of the criteria for evaluating the quest, etc. To do this, students were grouped and an online joint analyzed one of the resources offered in the selected cloud service.

In the second lesson "Technology for developing web-based quests using cloud services" skills of development and creation of a model of future site-quest are formed. The first stage involved discussing the conclusions of an independent analysis of the quality of one of the proposed quests and defining the criteria for their evaluation, as well as jointly creating forms in Google Docs and Google Forms for assessing the quality of web-quests, including of site-quests. They identified three sets of criteria. The first group included characteristics regarding the presence of the following elements: the purpose of doing the quest, the algorithms of work of the teams, reference material or references to it, instructions for the tasks, evaluation criteria, the timing of the stages of the quest, etc. The second group consisted of criteria for evaluating the quality of the design of the placed materials: reference material (taking into account the age characteristics of the target audience); sources; clarity and comprehensibility of tasks, instructions for their execution; performance evaluation criteria, etc. The third group included - the relevance of the content of the submitted material to the purpose of the quest; observance of copyright; organization of transitions between stages of the quest; quality of sources of information for processing when performing tasks; ways of organizing interaction between the participants of the quest; availability of memo for reflection.

In the next stage of the class, students were asked to choose a topic and to formulate the purpose of creating a future site-quest. To do this, they needed to: 1) select a course and become familiar with its program; 2) determine the theme of the future site-quest; 3) to formulate the purpose of its creation, taking into account the content of the educational material and the achievements of the students identified in the program.

Let's give as an example the experience of teaching future teachers the creation of a site-quest "School of young programmers".

Students selected one of the sections of the subject "Informatics" – "Fundamentals of algorithmization and programming" (for elementary school students). The purpose of creating a site-quest is to get acquainted with the concepts of "program", "object", "algorithm"; properties and methods of objects; software projects and principles for creating them in a visual application development environment, etc. To increase

students' motivation for learning the topics of this section, the Scratch Interpreted Dynamic Visual Programming Language (online) was used; each page of the site-quest corresponded to one of the topics of the section; offered theoretical material, tasks for practical and independent execution were presented in the form of mind maps, interactive posters, presentations, screencasts, interactive games and more.

To determine the content of the site-quest content, students were asked to: 1) analyze available distance courses or sites designed to master the basics of the Scratch programming language; 2) develop a study plan for the selected section; 3) discuss the content of training, types of training materials and tasks, possible ways of organizing the presentation of their implementation (see Fig. 2).

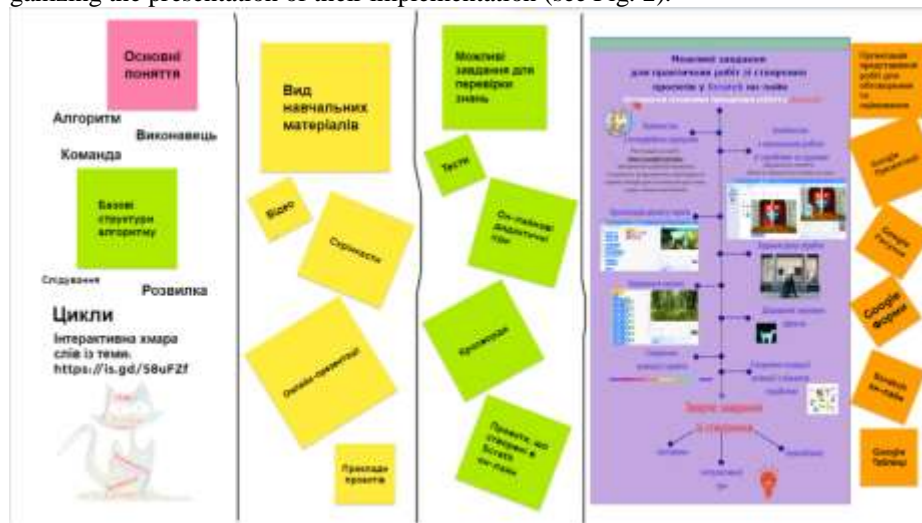


Fig. 2. The completed virtual interactive whiteboard for discussing the content and training forms of the selected topic (<https://cutt.ly/UtTa08P>).

Students independently selected material on the topic "Algorithmization. Basic structures of algorithms" and "Programming in Scratch": compiled a list of basic concepts in this topic and created a cloud of words; determined which materials will be provided for study and which should be given in the examples; formulated tasks for independent or practical implementation by students; chose ways to test knowledge, present and evaluate projects created, etc. The result of the students' activity was the development of the structure of the future site-quest, the definition of content for its filling.

The students also shared the responsibilities of completing their chosen tasks, including: the creation of didactic materials in the form of a cloud of words, infographics, interactive posters, online drawings and presentations, screencasts, interactive exercises, questionnaires, project examples and the site itself.

The third lesson, "Creating a Site Structure and Filling Content of Quest", was the final joint creation by students of the site "School of Young Programmers" using Google Site, its presentation, and subsequent reflection. Students analyzed the sites created; determine whether the learning aim has been achieved; discussed the advantages

and disadvantages of organizing their joint activities to create a site-quest using cloud services.

5 Conclusions

Summarizing the above, the following conclusions are drawn:

1. It has been found that there are objective prerequisites for finding ways to enhance the skills (ability) of future teachers to use cloud services effectively in the educational process, in particular, to create elements of gamification, one of which is a web-quest.

2. We have developed a methodology of training the creation of a site-quest by using cloud services, which involves six stages. Its realization helped to activate the creative and cognitive activity of students, to form in them the ability to search, process and analyze information from various sources; the ability to generate new ideas (creativity), to work autonomously and in a team, and so on.

3. Students will be able to apply the acquired skills to create pedagogical scripts of web-quests and appropriate didactic tools for their realization using cloud services, in particular, during the passage of various types of pedagogical practice. In the future, their competencies will become the basis for innovations in professional activity.

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Implementation of E-assessment in Higher Education

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Abstract. The purpose of the study is to develop the methodical recommendations for test-designers to cope with challenges of organizing on-line assessment process. In order to achieve this goal we have to reveal the strengths and weaknesses of e-assessment activities based on analysis of the universities practice. To find out students' attitude to the issue of the study we have drawn up the questionnaire. The survey results confirm that e-assessment is rated as priority activity by learners thanks to individual approach to teaching/learning process, easily accessible and fast feedback, as well as interactive methods of implementation. Reviewing practical experience of Kryvyi Rih National University (KNU) and Donetsk Law Institute of the Ministry of Internal Affairs of Ukraine (DLI) and summarizing statistical data of the survey we have developed methodical support for designing e-assessment activities which involves: to determine intended recipients and the purpose of testing; select appropriate instruments and e-platform; specify forms of feedback; clarify the tasks; provide knowledge base for operating e-tests etc. Despite plenty of studies in this domain the test-designers and test-takers face to typical difficulties while operating e-assessment, and there is lack of research providing methodical practicalities in this field. To address learners' and lecturers' needs we have developed the methodical recommendations, which might be used in the drafting of e-assessment tests for students of different specialisms.

Keywords: E-assessment, E-learning, Google Class, Moodle, Higher Education

1 Introduction

Problem statement. Technology is an integral part of student lives they use computers, mobile phones and the Internet every day. Nowadays it is important to use Information and Communication Technologies (ICT) for teaching, learning and assessment. E-learning has become an intrinsic element of prospective specialists' training. This approach contributes to provide basic knowledge and to improve awareness in any domain to the same extent. To compile qualitative, valid tests and develop accurate evaluation tools are among the main outstanding challenges. The text should have a measurable outcome; there should not be any flows as regards the content [18]. Nowadays there are

a lot of studies devoted to e-learning in the higher education system. E-assessment is considered to be an essential constituent of e-learning, which is commonly adopted in situations of necessity quick and effective testing of knowledge in large academic groups for example. This is regarded as a demanding, time-consuming and labour-intensive method of e-learning. But when tests are carefully designed, preferential advantages obtain both learners and teachers. E-assessment has become particularly relevant in view of global quarantine with regard to the spread of the virus around the world. At one moment a huge amount of institutions lost access to traditional in-class studying. In current situation e-learning and e-assessment are literally the only way to continue training, to measure knowledge and ensure that learning outcomes are met.

Analysis of recent research and publications. The scholars have concluded that online assessment is a significant technological advancement that should be involved in the educational system and enhance the current evaluating system. The scientific papers are dedicated to the principles of e-learning (Buzzetto-More, 2007; Pinhey, 2007), computer simulation and modelling in professional training (O. Teplytskyi, I. Teplytskyi, S. Semerikov, V. Soloviov, 2015) and computer-based assessment strategies (Miller, 2012). The scientists investigate the impact of e-assessment on the education (Vipin Singh, 2019), provides the guidance to teachers on how to construct e-tests (Zabaleta, 2013; Abdelkader, Boumiza, Braham, 2014; Mostert, 2012) and e-assessments (Forester, 2007; Pinsonneault, Kraemer, 1993; Koneru, 2017), study their attitudes towards the use of e-assessment (Tuparova, Goranova, Voinohovska, Asenova, Tuparov, Gyudzhenov, 2016), define the advantages and challenges of its using (Alruwais, Wills, and Wald, 2018; Upasana Gitanjali Singh, 2014). However, despite a considerable amount of studies, the methodological recommendations for efficiency in organizing e-assessment in higher education have not been provided. The academic literature on the subject has revealed the emergence of several advantages of e-assessment. For example, N. Alruwais, G. Wills, and M. Wald (2018) note that students prefer online assessment because they can control the process due to friendly interfaces. Besides, e-assessment ensures immediate feedback comparing with paper tests. It, therefore, increases students' motivation. Successful online interaction allows students to demonstrate not just content mastery but the ability to taking it to the higher level of thinking [2]. It helps students in remote areas to learn and assess their results [3]. In terms of universities, the advantages are clear too, i.e. it gives an opportunity to increase the number of students; e-assessment decreases cost for an institution to assess students as the time is reduced; e-assessment is reliable and security-enhanced, it assists to reduce students' cheating [3]. Additional benefits of e-learning and e-assessment are:

- The implementation of active learning strategies [2]
- Solutions for individualizing instruction [2]
- Replicability and accessibility [2]
- Ease of learning management [2].

The article is aimed to examine the practical experience of e-assessment on the examples of Kryvyi Rih National University and Donetsk Law Institute of the Ministry of Internal Affairs of Ukraine and reveal the advantages and disadvantages of this approach. **The outcome of the study** stems from the aim. It should be methodical recommendations for test-designers how to organize effective e-assessment based on analysis

of scientific literature on this subject and currently available e-tests on the universities' e-platforms, and summarizing of the results of the questionnaire for the university students. In order to achieve these outcomes, the following **tasks** are to be solved:

- an overview of recent scientific researches related to e-assessment;
- designing the questionnaire for students to define their experience of using different forms of e-assessment;
- analysis of the questionnaire results and identifying the pitfalls of e-assessment applying;
- examine the experience of using e-assessment in higher education;
- developing methodical recommendations for organizing effective e-assessment.

2 The Theoretical Backgrounds

Analysis of scientific literature was produced in terms of applying existing theories and practical experience. S. Hadjerrouit states that an e-learning model needs to demonstrate what pedagogical principles and learning theories are operating [8, p. 27]. It is really determining factor to realize how to implement the pedagogical theory into practice. Our study is based on the learners'-centered approach. All the tests and quizzes are subjected to meet the learners' needs in the scope of ESP.

In general, the researchers have determined that the life-cycle of e-learning model includes four phases. They are the design phase, the production phase, the deployment and assessment phases [1]. Our study is aimed to analyze the specifications of the last one. Evaluation is a really important phase of both classic in-class instructor-led studying and e-learning as well. In this regard, L. Forester (2007) investigated the differential impact of paper tests, web-based instruction and e-assessment on German culture proficiency of students. She notes that classroom teaching in "...a culture course – and especially assessments such as tests, quizzes, and papers – usually does not meet learners' actual linguistic needs" [6, p. 84]. The reason is a clear misalignment between real-life tasks in this domain and a set of facts which are necessary to complete the standard tests in class. Taking into account these disconnects the researcher has developed the author course on German culture based on German websites for cultural and linguistic information.

As a logical extension of a web-based approach to teaching the scholar has required students to submit all their work as web-sites. In particular, each student has created his own course web-site and posted all homework and projects there. And the benefits are clear because the students obtained new and very important for career promotion skills in web-sites designing, it encourages a more serious and responsible attitude to homework, contributes to the accuracy of facts, grammatical correctness, vocabulary usage, since not only group mates and a teacher could access to their results but everybody around the world.

Spanish researcher F. Zabaleta notes that "...the test-authoring software should provide a flexible array of item types and item capabilities" [21, p. 680]. For example, item feedback, conditional feedback, test evaluation feedback, printing, passing score, ad-

ministration of the test through a network. Meanwhile, B. S. Bloom was correct to assert that the role of an instructor also changed from the classic “sage on the stage” to the “guide on the side” [5, p. 90]. The teacher should explain technical questions, for example how to create frames on a web page and after that, the teacher served as a linguistic consultant [5].

Considering the fact that most of the e-tests have been designed conforming to Bloom's taxonomy principles let us expand on classifying educational objectives and test exercises. Bloom's Taxonomy is conducive to convert the objectives, which the teacher expects to perform, to practical applicable outcomes, which are expected by the learners'. The first (basis) step is *knowledge*. In the terms of evaluation knowledge “...includes those behaviours and test situations which emphasize the remembering, either by recognition or recall, of ideas, materials, or phenomena” [5, p. 62]. B. S. Bloom identifies several types of knowledge: 1) knowledge of specifics (to recall some specific information), 2) knowledge of terminology (specific verbal and non-verbal symbols). It is considered to be the most basic type of knowledge in some domain. There is an implied hierarchy to Bloom's categories, with knowledge representing the simplest level of cognition and the evaluation category representing the highest and most complex level. Teachers can identify the level of chosen learning objectives and create assessments to match those levels. One can write items for any given level. With objectively scored item formats, it is fairly simple to tap lower levels of Bloom's taxonomy and more difficult, but not impossible, to measure at higher levels. On the other hand, test-designers should not worry too much about the fine distinctions between the six levels as defined by B. S. Bloom. For example, comprehension and application are commonly treated as synonymous as it means the ability to apply what is learned that indicates comprehension [13]. Most e-testing theorists and test-designers today pay the most attention to the distinction between the knowledge level and all the rest of the levels.

Bulgarian scholars D. Tuparova, E. Goranova, V. Voinohovska, P. Asenova, G. Tuparov, I. Gyudzhenov have conducted the survey to find out what methods and technological tools for competency assessment apply school teachers of Maths and Informatics in Bulgaria [20]. The results show that the teachers prefer “...traditional assessment methods as Tests, Practical Tasks and Project-based method. Most non-used methods are Method 360 degrees, Portfolio, and Sharing opinion through social networks” [20, p. 2239]. Consequently, the research discloses the fact that e-designers prefer to develop simple lower levels of e-assessment items (according to Bloom's Taxonomy). The scientists make the public one of the reasons for non-using higher-level methods, which has proved to be the lack of knowledge on the method or the belief that this method is not suitable for the subject. Thus, this research has indicated a need for additional methodical support for lecturers who do apply e-learning and e-assessment in practice.

3 Methods

In order to identify whether the students have got enough experience of using different forms of e-assessment the participants were asked to fill out the questionnaire. Firstly, we have developed the questions for the survey. A. Pinsonneault and K. L. Kraemer define a survey as “a means for gathering information about the characteristics, actions, or opinions of a large group of people” [14, p. 77]. Surveys can also be used to assess needs, evaluate demand, and examine impact [15]. The survey enables us to collect the necessary information on students’ attitudes towards using of e-assessment; to mature advantages and disadvantages of these methods and appropriate implementation of the electronic evaluation. The questionnaire was made available on the Internet and redistributed among the students of Kryvyi Rih National University and Donetsk Law Institute of the Ministry of Internal Affairs of Ukraine. We use Google Forms as an instrument to provide and collect regular students’ feedback regarding their learning experience. Dr. R. Haddad and Dr. Y. Kalaani characterize Google Forms as “an integrated web-based application that facilitates the design of online surveys, questionnaires, and quizzes with a user-friendly application programming interface (API)” [7]. The scientists indicate the following benefits of using Google Forms: 1) it has a modular structure which makes creating surveys as easy as adding questions and selecting options such as the type of question, the scale, and the labels; 2) the survey results are stored in a centralized Google Spreadsheet in your Google Drive and can be exported to Excel spreadsheet; 3) Google Forms does not limit the number of survey forms that can be created or the number of students that can participate in these surveys; 4) it allows email notifications whenever a response is submitted; 5) it supports a wide range of question types and options and etc. [7]. Thus, the survey has been placed on Google Forms platform because it enables to get fast feedback, to monitor the progress and analyze the results. There is the link: <https://forms.gle/zYJupAyvBffsuokdA>.

	Often	Not very often	Never
Multiple choice (There are several answers from which you should choose only one.)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Short answer (There are open-ended questions that require students to create an answer)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

Fig. 1. Google Forms

Let us now consider the results of the questionnaire. The total number of respondents is 111 the 1st – IVth year students of KNU and DLI trained for different specialisms, namely computer and software engineering, electrical engineering, mechanical engineering, economics, management, law enforcement, law. At the beginning of the study, students were informed about its goals, and they agreed to cooperate on a voluntary basis.

The first question is aimed to identify which forms and methods of e-assessment students have experienced on different subjects at their universities. Of the 111 respondents who completed the questionnaire, just over half have indicated *multiple choice* (76 respondents), *short answers* (56 respondents) and *presentation* (57 respondents) as the most often used forms of e-assessment. There are highly predictable results because of the teachers remarkably regular use those forms for quick testing of their students' knowledge.

Otherwise, such forms of assessment activity as a case study (*Not often* – 66 respondents, *Never* – 17), self-assessment and peer-review (*Not often* – 54 respondents, *Never* – 13), discussion posts (*Not often* – 61 respondents, *Never* – 13) and portfolio (*Not often* – 36 respondents, *Never* – 36) have appeared to be underestimated by the teachers. The findings of the questionnaire have revealed that crucial number of students has experienced these methods “not very often” or “never”. The reason is self-evident: this is a cumbersome and time-consuming process to develop aforementioned activities for test-designers, on the one hand, and this is labour-intensive and meticulous to complete these assignments for test-takers, on the other hand. It becomes apparent that the results we found have been echoed by the larger-scale study conducted by Bulgarian scholars [20].

This assumption is supported by the answers on the questions as concerns the advantages and disadvantages of the e-assessment methods. Figure 2 below illustrates the breakdown of the students' choices according to the advantages of the most often used electronic evaluation methods.

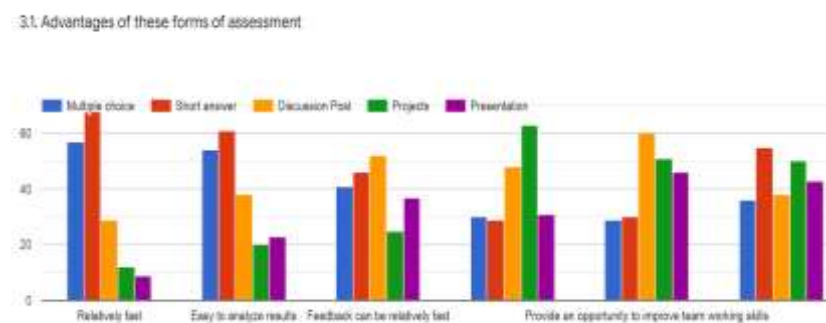


Fig. 2. Advantages of e-assessment methods

It is significant, therefore, the respondents have cited amongst the disadvantages of e-assessment methods lack of accuracy provided by multiple choice (45 answers) and short answers (45 answers) whereas the students may often learn by rote or just guess the answers (59 and 54 answers, respectively).

The next section of the survey is concerned with the problem of students' awareness of the long-run objective of different e-assessment methods. We have addressed the question: *What skills and abilities do these forms of e-assessment contribute to?* Table 1 displays the distribution of skills and abilities among the forms of assessment in the view of the test-takers.

Table 1. The distribution of answers to the question "What skills and abilities do these forms of e-assessment contribute to?"

	Multiple choice	Short answer	Discussion post	Projects	Presentation	Portfolio	Case study	Reflective journals	Practical experiments	Self-assessment peer-assessment
Critical thinking	54	49	54	38	25	33	40	21	58	35
Communicating skills	33	38	54	36	47	23	49	33	44	38
Analytical and research skills	48	33	41	54	43	46	42	46	58	29
Ability to make decisions and solve problems	54	44	51	45	24	37	35	34	52	36
Leadership or management skills	28	27	47	53	42	31	35	29	59	33
Ability to plan, organize and prioritize work	40	29	37	58	42	48	43	36	58	30
Teamwork	47	29	55	54	40	37	35	27	61	40

The single most striking observation to emerge from the data comparison is that a significant number of respondents realize that time- and labour-consuming but creative assessments methods like presentation, portfolio, case study, practical experiments are crucial for improving learners' proficiency. For instance, 58 of 111 students noted that *practical experiments* contribute to critical thinking, analytical and research skills as well as ability to plan, organize and prioritize work. This form of learning activity has "...enabled the lecturers to identify the practical skills acquired by the students as well as their weaknesses in performing the experiments" [16]. The potentialities of on-line practical experiments are not confined to the assessment of practical skills. Test-takers may answer the questions, describe or explain their observations and demonstrate the awareness of the significance of the theoretical knowledge they had obtained at in-class instructor-led classes. Experience has shown, 61 of 111 students, that practical experiments successfully combined with project activities may be used to assess team working skills too.

On the other hand, the survey has revealed that the learners do not sometimes understand the educational goals of some e-assessment tasks. For example, 47 of 111 respondents mentioned that *multiple-choice* exercises improve team working skills, and 44 of them answered that *short answers* develop their ability to make decisions and solve problems. None of this is true but we cannot accuse the students only because the lectures' responsibility is to instruct and explain the tasks clearly. Over and above, the test-designer is required to inform the test-taker about the place, role and importance of the assignment in the whole system of professional knowledge.

Together these results provide important insights into the state of affairs in practice. Data analyzed for the purpose of this study indicate that both lecturers and learners are interested in on-line assessment activities. However, all relevant stakeholders obviously need methodical assistance in e-tests' designing and their completion. The results of the survey have become really meaningful to develop methodical recommendations for test-designers.

4 Findings

Moving on now to consider the practical ways of addressing the e-assessment issue. Dr I. Koneru supposes that the Learning Management Systems (LMS), such as Moodle (Modular Object-Oriented Dynamic Learning Environment) supports the integrated e-assessment systems. It provides formative (self-assessment, peer assessment, tutor-marked assignments), summative and competency-based assessment [10]. In our teaching practise, we use self-assessment through self-check exercises and in-text activities, continuous and tutor-marked evaluation through topical assignments and summative assessment through term-end tests on the Moodle platform. The Final tests [<http://mlib.knu.edu.ua/course/view.php?id=20334>] in English for specific purposes (ESP) for first-year students of Information Technology and Mechanical Engineering faculties have been developed taking advantage of Moodle quiz feature which enables to organize a time-bound activity and supports various questions types by KNU lecturers. The term-end tests consist of 100 different type questions namely, multiple-choice questions (MCQs), matching and short answers. It was identified that MCQs can be adopted more than just recall questions (lower cognitive levels of Bloom's taxonomy). Hence, Upasana Gitanjali Singh notes a dual role of MCQs – to obtain information on the different types of MCQs, as well as how applicable these types are to stimulating higher-order thinking skills (HOTS) in the students [17, p.138]. Test questions are shuffled so that each student will get a different assignment. This reduces to a minimum the potential for cheating at the test. Additionally, the students can see the correct answers as soon as the quiz is completed by all the respondents; this, in turn, prevents sharing the information with group mates. Students' answers are checked and recorded automatically that makes assessment error-free and delivers instant feedback. Automatic grading helps the learners accurately track their progress and creates a reliable e-assessment system. The quiz is divided into two parts: Grammar (60 questions) and ESP (40 questions). Grammar quiz is illustrated in Figure 3.



Fig.3. Word-formation assignment of grammar block

As noted previously, the final assessment is appropriate to ascertain the level of students' proficiency in a discipline. As a rule teachers use this kind of activity at the end of the course. Final assessment can be viewed as a formative assessment when the student uses it as a foundation for the work in successive courses, for example, a project in the first year can be a support to learning in the second year of study [17, p. 31]. Furthermore, the consistency of electronic marking removes concerns associated with subjective manual marking by the human assessor. The formative assessment (FA) can be the transitional phase between enrolment and final assessment phases. Its knowledge building role is undeniable. It is contributed to the sustainable improvement of language skills and facilitates to obtain the looked-for results in learning outcomes. One of the e-assessment benefits is that it might be viewed as a wake-up message for a lecturer in regard to if the students have adopted the material or not. In this context, the Moodle platform gives a wide range of instruments and tools, notably very comprehensive reports including time taken, number of attempts, date of start and completion, charts data with the overall number of students achieving grade ranges and so on (Figure 4).

Grade	Count	Percentage	Grade Range
Finished	2020	100%	0.00
Failed	0	0%	0.00
Not Started	0	0%	0.00
Not Attempted	0	0%	0.00

Fig.4. Charts data of students achieving grade ranges

The special ESP course “English for Mining Mechanical Engineers” (KNU) [http://mlib.knu.edu.ua/mod/quiz/report.php?id=13415&mode=overview] is targeted for the fourth- and fifth-year students of engineering majors based on Moodle platform. The on-line platform provides different grades reporting services for formative assessment, thus helping test-designers to collaborate with students and making work of both of them easier. The objective of the special course is to improve students' reading, listening, writing and speaking skills within the professional engineering context. Consequently in formative assessment what is really important for test-takers is to get quick feedback, and to be able to analyze the results and understand the mistakes.

The course “Competition law” (DLI) [<https://elearning.dli.donetsk.ua/course/view.php?id=116>] has been designed according to these principles as well. New material is represented as a lecture then the theory is supported by the thematic presentation and the third block consists of three types of assignments such as “Explore the problem...”, “Explain the phenomena...”, “Compare ...and give reasons for your choice”. The assessment is designed in the forms of discussion posts, case study and self-assessment (Figure 5).



Fig.5. Course “Competition law”. Topical Unit 1.

The theoretical block is followed by appropriate individual work and the in-depth study block. There are some options in this part of the Unit. At first, the students are offered to train their analytical and research skills and complete the tasks, for example: based on the current competition law, do some research on the impacts of the norms of economic competition on the relationships occurred outside the territory of Ukraine. The next task looks like a discussion post: determine the role of competition in entrepreneurial activity; justify your point of view. Finally, the students are proposed to organize themselves into groups (3-4 people in each one) and develop topical projects. There are three topics among which they can choose one, develop the project and represent it in class. In such a way they implement the theory into practice and train team working skills. All the assignments are collected in a folder that is how a student’s portfolio has been created. This midpoint assessment is primarily aimed at sending a message to the teacher: “OK. We are ready to continue!” or otherwise “Hang on a minute! We cannot keep up”. E-assessment significantly speeds up the feedback and facilitates fruitful interaction of the lecturer and the learners. All the question and assignment types discussed above can, in an e-assessment system, include high-resolution graphics, video, sound, animations and other multimedia elements which are used as part of the questions and not just as decorative images [11]. Figure 6 demonstrates the practical implementation of these principles in the course “English for cadets of the major “Law Enforcement Activities” [<https://elearning.dli.donetsk.ua/course/view.php?id=188>]. These questions can be adapted to test the higher cognitive levels of Bloom’s taxonomy [12].



Fig. 6. Combination of multiple choice questions and audio elements

The use of Moodle in the process of students professional training by means of computer modelling provides for the use of its tools to achieve the desired learning outcomes, and also the harmonious combination of traditional and distance learning, the formation on their basis of open information and educational environment (information and communication systems and traditional means aimed at organization of students educational activities) [19, p. 130].

Google provides a great number of tools to develop tests and tasks of e-assessment. For example, Google document gives an opportunity to choose the way of tests accomplishment individually. The learners are not limited by a rigid framework with fixed time or ways to fulfil. Figure 7 displays a vocabulary test. The purpose of the test is to provide diagnostic feedback to the learners, as well as to inform the lecturer about the necessity to tailor the course more closely to the needs of this group of students [4]. The test-takers are given specific sets of words to be filled in the right context of the given sentences. The specific of the test is that the words are synonymous and can be used more than once.



Fig. 7. Vocabulary test on Google Class platform

As we can see in the figure the learner's approach to the test completion is creative enough. Different colours are associated with each of the words. It does not create additional pressure and can be an additional motivation to improve English grammar and vocabulary.

Google Class platform provides the test-designers with a wide range of e-assessment instruments, which enable to systematize, analyze and follow the whole group progress as well as an individual student' results. Figure 8 illustrates the portfolio of KNU academic group.

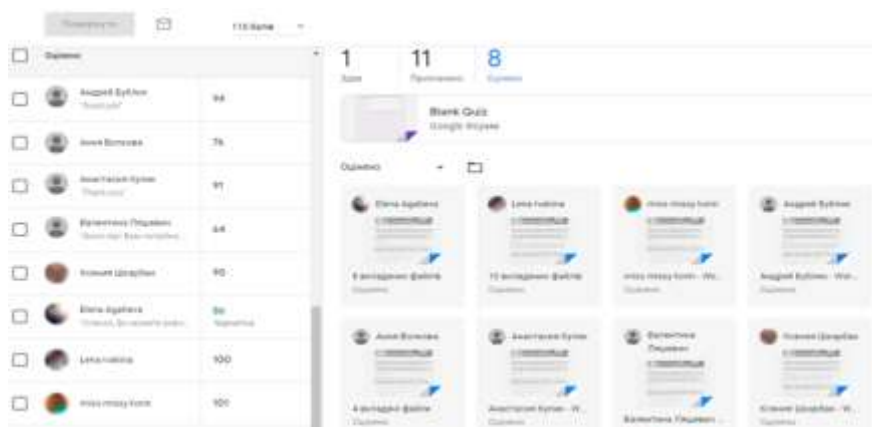


Fig.8. Portfolio of the academic group on Google Class platform

Analysis of the practical experience of Kryvyi Rih National University and Donetsk Law Institute of the Ministry of Internal Affairs of Ukraine demonstrates convincingly that an extensive choice of e-assessment tools contributes to the practical implementation of individual approach, allows correcting the content of the courses and tailors them according to students' needs. For another thing, the e-assessment toolset confers the possibility to instruct each of the test-takers individually, to inform them about the test results in confidence not to hurt their pride. In addition, we cannot fail to mention that e-assessment approach facilitates implementing of interactive learning strategies. In fact, as we have said, this approach switches the role of a teacher from a manager to a facilitator; it encourages learners to be involved; it is expected students to participate in learning/assessment process. Implementation of e-assessment provides practical experience of using information and communications technologies for both test-designers and test-takers.

5 Conclusions and prospects for further research

Theoretical study of recent scientific researches in regard to the e-assessment issue has consolidated our hypothesis that despite the labour and time-consuming of this approach, it is advanced, highly developed and upgraded constituent of e-learning targeted at measuring learner's progress, which provides substantial benefits for both

stakeholders. The conducted survey has revealed the advantages of on-line testing activities taking into consideration the test-takers' point of view, they are student's friendly environment, fast and easily accessible feedback, an opportunity to keep privacy and work individually, at the same time there is a good chance to improve team working skills depending on the activity. However, the students note such disadvantages of e-assessment as lack of accuracy because of learning by rote/guessing the answers of most commonly used forms of e-tests, namely multiple choice and short answers; one more problem they have to cope with is that it is impossible to assess oral speaking or writing skills using some forms and activities. The purpose of the current study is to develop methodological recommendations for organizing and effective implementation of e-assessment in higher education based on the practice of Kryvyi Rih National University and Donetsk Law Institute of the Ministry of Internal Affairs of Ukraine. Review the current usage and feasibility for various e-assessment tools enables to conclude that e-assessment has already become a congruous component of prospective specialists' training; university teachers entrench e-assessment in view of individual approach to studying and meeting individual student's needs; the test-designers successfully deal with different levels of testing complexity according to Bloom's taxonomy. Notwithstanding any advantages contained herein, these revealed a number of problems; in particular, the test-designers require support in developing the criteria for assessing student's proficiency; lectures may find it difficult to develop reliable assessment instruments to evaluate particular skill; the teachers also experienced difficulty with formulating the instructions clearly. By and large, the study is targeted to cope with mentioned challenges.

Taking into account theoretical and practical experience we have developed the methodical recommendations for e-test-designing. The research has shown that the test designers should follow the algorithm which includes several steps to succeed. They are:

- to determine *who the test-takers are*; the purpose of the test is a starting point for any assessment activity;
- to define the skill/skills are to be tested and assessed; it would be a marked advantage if e-test includes a short description of the ability is the test aimed at in the context of the discipline;
- to choose appropriate tools for developing e-assessment tests and tasks (Moodle, Google or any other);
- to develop clear criteria for assessment, specific characteristic and settings such as time constraints, scoring method, and e-platform to display the test;
- to specify forms of feedback; it might be represented as data results, a graph, a piece of advice, comment, response, opinion, survey rating; The feedback must be a meaningful tool for test-designer because it is the only way to evaluate and encourage the learner;
- e-assessment should focus on things that matter and things that can be controlled; in other words, it should be representative for the domain;
- to provide necessary knowledge and e-tools for test-takers to operate the test and its feedback;
- to give clear and effective instructions;

- to determine what the expected outcome is.

Consequently, the teachers are provided with ample opportunities to develop concepts and e-tools in relation to e-assessment. The lecture should take full advantage of e-assessment to meet individual student's needs, for example, he can complete the e-test at his own pace, to have several attempts to complete the task, to get immediate feedback and analyze the mistakes, to discuss the results with the other test-takers and the test-designer etc. E-assessment provides privacy, fairness and objectiveness of results, everyone is in equal condition, no one can impact the results. In addition, this way to assess the students' knowledge excludes cheating at the test, to a great extent.

The study suggests that different forms of e-assessment have a positive impact on the training of prospective specialists in different industries. Successful online interaction allows students to demonstrate not just content mastery but the ability to incorporate theoretical content into practice, which is particularly valuable to beginning practitioners.

A further study could assess the long-term effects of e-assessment forms on learning outcomes on different subjects and developing appropriate criteria of e-assessment activities as well.

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Cloud services in the distance learning system for future sailors

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Abstract. The widespread use of distance learning platforms and office services, in particular spreadsheets, sets the task of their integration, for example, for using Excel documents in distance learning systems (DLS). Using cloud services can be a technological solution to this problem. The advantage of using cloud services is access to information resources using only an Internet connection and a web browser.

The aim of the study is the development and implementation of the ExcelReader software module for using Excel spreadsheets on the web pages of the distance learning system.

The following tasks were solved in the work:

- 1) analyzed well-known software solutions for displaying Excel documents in web applications and training platforms;
- 2) an effective technology for programmatically processing Excel documents was selected;
- 3) a model of a system for accessing and using web services for processing Excel documents in DLS was developed;
- 4) the ExcelReader software module was developed for displaying and editing Excel documents on web pages in the distance learning system;
- 5) The program module "ExcelReader" is implemented in DLS "Moodle KMA" and "Kherson Virtual University" (KVU). In particular, the ExcelReader software module was introduced into the educational process for using Excel spreadsheets on the web pages in DLS KVU using the Microsoft Excel Web App cloud service.

Keywords: E-learning, iCloud services, Excel, embedding, distance learning, Kherson Virtual University, Moodle KMA, infrastructure.

1 Introduction

One of the tasks of the education system in modern society is to provide each person with free and open access to education throughout his life, taking into account his interests, abilities and needs. Therefore, learning management systems (LMS) are becoming relevant [1]. Now, education does not depend on the geographical location of a person and becomes more accessible with the advent of distance education.

Among the main functional requirements for electronic educational resources in distance learning systems, the requirements of visibility and interactivity can be distinguished, both in lectures and textbooks, and in tests and virtual laboratory work. Among e-learning resources, Microsoft Office documents are widespread. Therefore,

there is a need to display Excel spreadsheets with data, graphs, charts on web pages of resources.

Using spreadsheets, the calculation and processing of a large amount of data is quickly carried out. Their visual and dynamic presentation allows you to almost instantly display the calculation results on a computer monitor. The main advantage of spreadsheets is that it is possible to instantly automatically recalculate all the data associated with functional dependencies when changing the value of any elements of the spreadsheet.

Due to its simplicity and ease of use, the possibilities of teamwork, interaction with Internet resources, and the provision of powerful data analysis tools, Microsoft Excel is one of the most common, popular tools for working with documents with a tabular structure.

Especially significant is the task of building a model of using Microsoft Office resources in distance learning systems. So, combined network models that are able to take into account the indistinct content of some information can be adopted as mathematical models of the information resource of a distance learning system [2].

In order for the electronic learning resource in the distance learning system, for example, Moodle KSMA [3], to be the most effective and visual, it is necessary to solve the problem of displaying Excel spreadsheets on the Web page with data, graphs, charts, as well as creating and editing an Excel spreadsheet, for example, in lectures, practical works, tests. As a result of this, there is a problem associated with the display of spreadsheets data on Web pages.

The main technologies for displaying spreadsheet data on Web pages are:

- saving MS Excel spreadsheets in an XML file with subsequent processing to display it on a Web page [4];
- development of a Web-based software module for supporting the use of spreadsheets in the LMS with the connection of software libraries for processing spreadsheets: Microsoft Office Online [5,6], Excel Reader.NET [7], Excel Viewer 2.0, and others for processing and displaying MS Excel spreadsheets on Web pages;
- the use of online cloud services for working with spreadsheets, such as OneDrive [8], Google Drive [9], Microsoft Azure [10] and others.

A simple and convenient solution to the described problem is the use of cloud services.

Researchers at the UNESCO Institute for Information Technologies in Education note that the acquisition and maintenance of various computer equipment and software in modern educational institutions constantly requires significant financial investments and the involvement of qualified specialists (Neil Sclater, Cloud computing in education [11]). As a cost-saving technology, cloud computing and virtualization of the computing platform are currently playing.

Using cloud services, you can access information resources of any level and any capacity with the separation of the rights of various user groups in relation to resources using only an Internet connection and a web browser.

The advantage of cloud technology is the management of large infrastructures, security, the absence of dependence on computer and software modifications.

Disadvantages include dependence on the availability and quality of the communication channel, risks of technical failures and legal issues.

Cloud services can be divided into three main categories [12]:

- Infrastructure as a service (IaaS);
- Platform as a service (PaaS);
- Software as a Service (SaaS).

An example of the use of cloud technologies in education is personal accounts for students and teachers, electronic journals, thematic forums where students can exchange information and much more. This is a search for information, where students can solve certain educational problems even in the absence of a teacher or under his guidance.

The object of this article is cloud services.

The subject of the study is Microsoft and Google cloud services in the distance learning system.

The purpose of the study is the design, development and implementation of the ExcelReader software module for using Excel spreadsheets on the web pages of distance learning systems, in particular, Moodle KSMA [3] and Kherson Virtual University (KVU) [13].

The following tasks are considered in the article:

- 1) to analyze well-known software solutions for displaying Excel spreadsheets in Web-based applications;
- 2) choose an effective technology for software processing of Excel spreadsheets;
- 3) to design a system for access and use of web services for processing Excel spreadsheets in a distance learning system;
- 4) to develop the ExcelReader software module for the correct display and editing of Excel spreadsheets on Web pages in distance learning systems;
- 5) introduce the software module "ExcelReader" in the distance learning system "Kherson Virtual University".

2 Statement of the problem

The use of cloud services in the educational process is an important resource not only for the teacher, but also for future sailors, as an example of their possible use on the ship.

In the field of training of marine specialists, the main focus is on teaching professionally oriented disciplines, such as "Theory of the ship's structure", "Navigation and the field", "Management of the ship", etc. However, the quality of specialist training is determined in all areas, including the ability to use modern innovative technologies in professional activities. The knowledge gained during the training should be sufficient to correctly operate computer equipment on the ship, to be able to use the information provided by the computer.

Especially important is the ability to quickly and accurately carry out calculations for skippers who, by virtue of their duties, must carry out navigation pads, determine the stability indicators of the vessel when empty and in load, evaluate the error in the

readings of ship's instruments, etc. The most widely used tool for this purpose is MS Excel spreadsheets, access to which can be obtained both from a stationary computer and from a mobile device on which the corresponding mobile application is installed.

The range of tasks that a professional skipper has to solve is quite wide. The program for the preparation of the skipper in disciplines focused on the use of information technology takes into account all aspects of his professional activity, including the tasks associated with the calculations as a necessary component of the navigator's terms of reference. Of course, special navigation programs are installed on ship computers, with which you can solve various navigational tasks. However, the vast majority of these programs are also executed in MS Excel. Spreadsheets are primarily intended for conducting various computational work, where it is necessary to process large arrays of numbers, which the navigator often has to deal with in his work. It should be noted that the crew of any ship changes periodically, and the navigator, arriving at the place of the one who was discharged from the ship, must quickly understand the structure of the calculations, understand their logic and be included in the daily work process.

However, the navigator does not always have access to MS Excel. With this in mind, an analysis of the possibilities of working with spreadsheet data in SaaS cloud services was carried out.

Thus, we set the task of developing methods and technologies for using cloud services in the educational process of future mariners in the LMS in the study of the above disciplines.

3 Modeling a learning system using cloud services

Some of the most popular cloud services include: shared hosting Amazon, TheRackspace, Google, Microsoft, iCloud, SugarSync, Dropbox, Joyent, GoGrid, Terremark, Savvis, Verizon, NewServers, etc.

There are some disadvantages of cloud technologies, which are mainly technical and technological nature. These disadvantages are limiting of functional properties of software compared with local analogues, the lack of native providers of cloud services (Amazon, Google, Salesforce etc. are concentrated in the USA), the lack of national and international standards, and the lack of legal framework applying cloud technologies in education.

Currently there are four models of cloud deployments:

- Private cloud - it is used to provide services within the organization that is both customer and service provider. It is the variant of cloud concept embodiment when the organization creates it's for itself in limited use;
- Public cloud - it is used to deploy of the infrastructure and software to provide access outside of boundaries of institution's infrastructure;
- Hybrid cloud - it is two or more different types of clouds;
- Community cloud - type of infrastructure, designed for use by the specific consumer society of organizations with common objectives. Examples, platform Windows Azure, Web services Amazon, Google App Engine and Force.com.

We study public and community cloud systems [14].

Cloud technologies make possible to integrate various active learning methods in the information environment. Let's consider the most popular and affordable for users Internet services:

- Google Docs is an online office to create various documents for share access;
- OneDrive – service of Microsoft, it is similar service of Google Drive;
- Scribd – Internet service of cloud document storage, which allows publishing documents prepared in the most popular formats: Microsoft Office, Open Office, Adobe Acrobat, etc.;
- Slideshare – online storage of presentations;
- Google Scholar – search engine of educational and scientific publications;
- YouTube – a service that allows you to download and watch videos in a browser;
- Skype – a service that provides audio and video communication;
- Wikipedia – online encyclopedia, based on wiki technology;
- ResearchGate, Academia.edu – social networking sites for scientists and researchers to share papers, discussions, and find collaborators;
- Blogger – Internet-service in the form of online journal (or blog);
- Facebook, LinkedIn – a social network that provides the ability to create study groups, business and employment-oriented communities, etc.

Consider two popular cloud services from Google and Microsoft for their use in distance learning systems. We list the main services that Google provides:

- Gmail - mail service;
- Google Sites – free hosting using wiki technology;
- Google Calendar – an online service for scheduling appointments, events and affairs with a calendar. It is possible to share the calendar with a group of users. The service is integrated with Gmail;
- Google Drive – cloud storage with the ability online (in the browser) to view the contents of many file types. There is support for popular office formats such as *.docx, *.doc, *.rtf, *.xlsx, *.xls, *.pptx, *.ppt, *.pdf, *.txt, *.html, *.jpeg, *.png, *.gif, *.zip, *.rar and others. Files downloaded to the disk with such formats can be opened, viewed, and some can also be edited online and offline directly in a web browser. The user is provided with storage up to 15 GB.

To use all of the above services, the user must have a Google account.

Now consider what is included in the cloud service from Microsoft:

- OneDrive – cloud storage up to 105 GB.
- Office Online (known before 2014 as Office Web Apps) – a tool for creating and processing MS Office documents created in Word, Excel, OneNote and PowerPoint.
- Outlook is email service.
- Calendar – a classic organizer.
- People – a means of communicating with your contacts on Facebook, Google, LinkedIn, Sina and Twitter.

To work in OneDrive and to use other services from Microsoft, you must have a Microsoft account.

Both of these services allow you to embed a document stored in cloud storage into the site. Microsoft, unlike Google, allows you to dynamically work with embedded documents on a web page.

It was this opportunity that played a decisive role in our choice of cloud service, since dynamic work with documents in distance learning systems is important for us.

An important feature is that this interactivity will allow the teacher, during the learning process, to demonstrate the relationship of the stated theoretical material with the practical use of interactive documents in the same system, and the student himself to apply theoretical knowledge in practice during the lesson, which will consolidate the learning results.

And all this will be possible within the framework of one LMS. For example, in a lesson, a simplex method is studied for solving problems using Excel spreadsheets. The teacher will be able to visually demonstrate to students the dependence of the solution of the problem on the values of its variables, as well as the student will be able to "probe" this method.

Features when working in Excel Web App: working with spreadsheets and books in a browser or in MS Excel for desktop computers (Fig. 1).

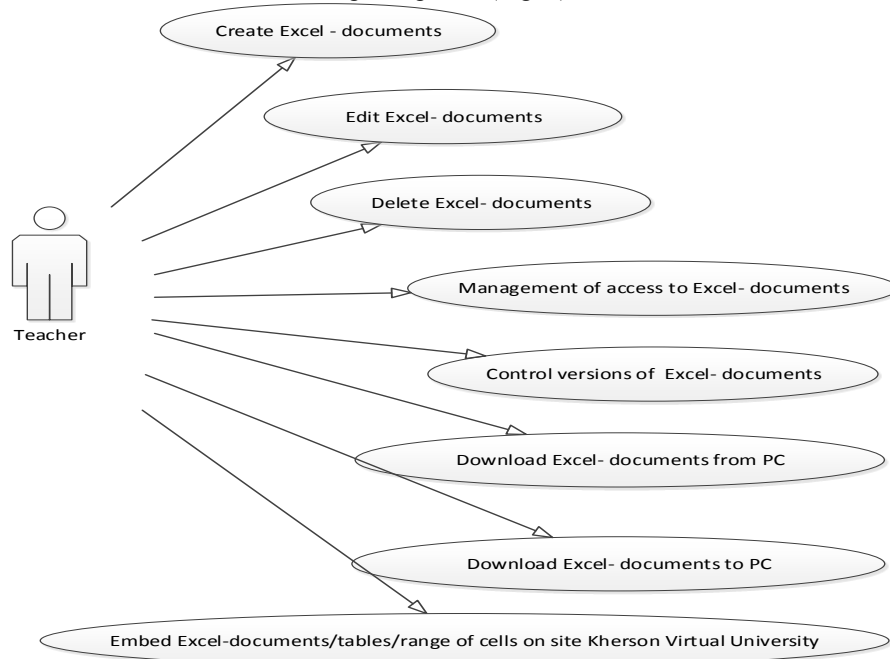


Fig. 1. Use Case-diagram “Teacher Features in Excel Web App”.

Consider the algorithm for inserting an embedded object into the html page of the LMS electronic resource using the example of a document in OneDrive [15].

To embed a Microsoft document in the text of an electronic learning resource, the user needs to perform a series of actions: authorize in OneDrive, create the necessary Microsoft document in OneDrive or use an existing document in OneDrive, configure access to this document, and configure its display on the resource’s html page, into

which the document will be embedded, receiving the html code and, finally, inserting this html code in the html page editor.

We will consider the implementation of an object from the Microsoft OneDrive service in an html page using the example of inserting an Excel spreadsheet into the electronic resource of the LMS KVVU. When the command to insert an object from the Microsoft OneDrive service is called, a request is sent to its address to add a table to the KVVU server, and the KVVU server, in turn, sends a request to the Microsoft server. After which the user authorization is checked, after the authorization is completed, all the files of this user are displayed, that is, the OneDrive document storage cloud service page opens. The user has the opportunity to create a Microsoft document (Excel, Word, PowerPoint, OneNote) or open a document stored on OneDrive for further work with him.

As an example, consider the processes of creating and editing Excel documents (Fig.2-3).

A prerequisite for adding an Excel spreadsheet to the text of the html page of an electronic learning resource is an account in the OneDrive service, therefore, when you request to add a Microsoft document, authorization will be checked in OneDrive.

To add an Excel spreadsheet to the text of an html page in the LMS, you need to configure the display of the document and access rights to it on the OneDrive website, as well as get the html-code of the document, for example, an iframe tag of the form:

```
<iframe width="402" height="346" frameborder="0"
scrolling="no"
src="https://onedrive.live.com/embed?cid=2B0C4195906D5E81
&resid=2B0C4195906D5E81%21197&authkey=ALxgdY4CVNRy7bk&em=
2&AllowTyping=True&wdDownloadButton=True"></iframe>
```

The attributes of the iframe tag contain information about the display size of the document we want to embed: width = "402" height = "346", display the frame frameborder = "0", the ability to scroll through the document scrolling = "no", as well as a link to this document and additionally displaying the ability to download a document to a computer:

```
src="https://onedrive.live.com/embed?cid=2B0C4195906D5E81
&resid=2B0C4195906D5E81%21197&authkey=ALxgdY4CVNRy7bk&em=
2&.
```

After that, it is necessary to insert the received code in the editor of the html page of the electronic learning resource and save the changes.

Similarly, PowerPoint Online, OneNote Online, and Word Online documents can be used.

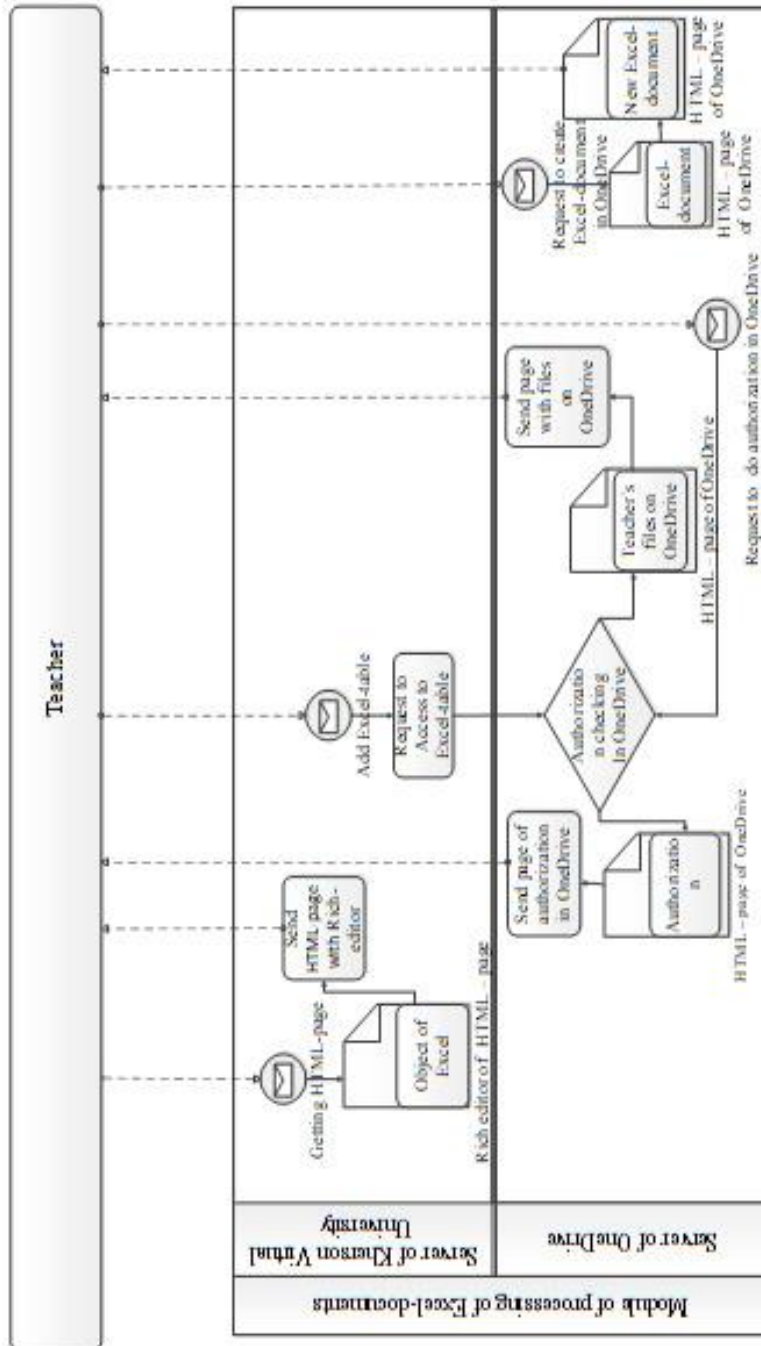


Fig. 2. Scheme of the model for creating an Excel document.

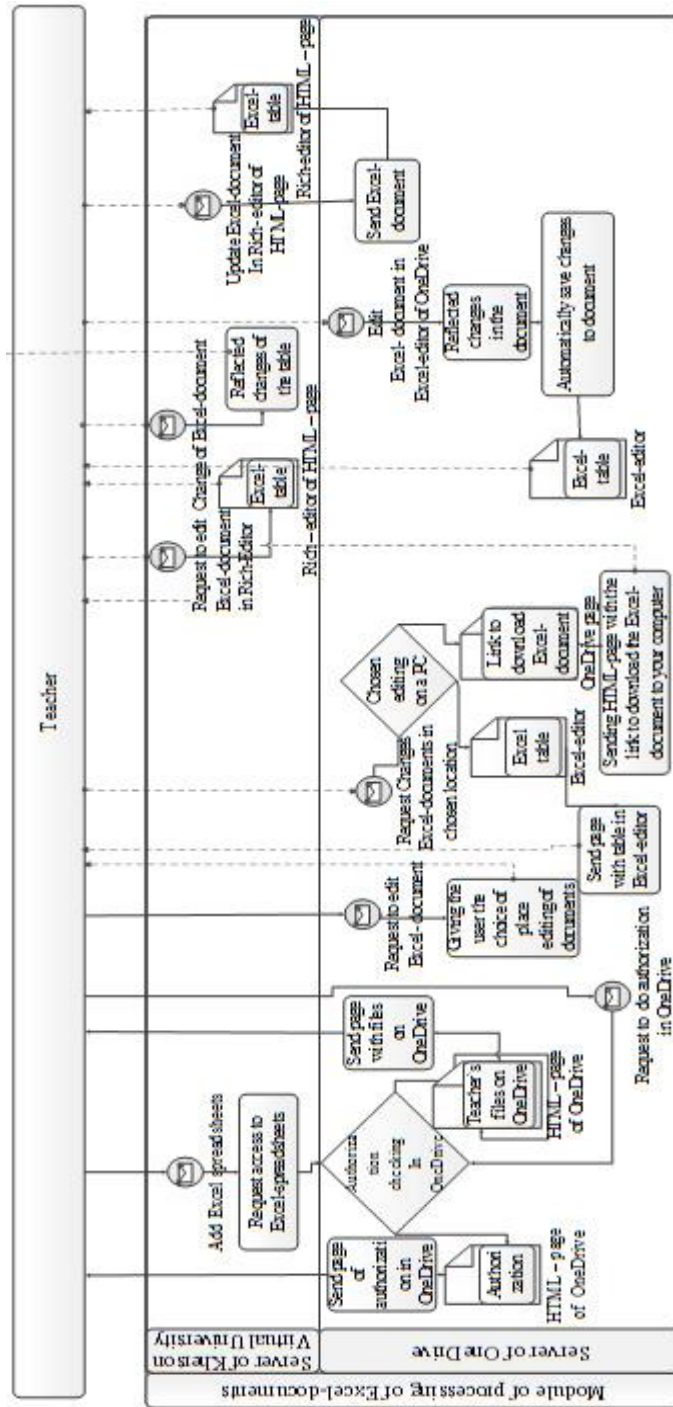


Fig. 3. Scheme of model of editing process Excel-document.

The following technologies were used to develop the ExcelReader module: JavaScript, HTML, .Net.

Consider the JavaScript code:

```
<script type="text/javascript">
<!--
var theElement = document.getElementById("div1");
//-->
</script>
```

`document.getElementById` - method of the document object. It returns a link to the document node, which can be used to change properties and access node methods. We use this method to find a place in the code where the document will be embedded in the future.

Now consider the html code used to insert a document into text:

```
<form name="my_form" id="my_form" action="#"
method="get">
```

Insert HTML - code:

```
<input type="text" name="content" id="content" size="60"
/>
<input type="button" value="Send"
onclick="theElement.innerHTML =
document.my_form.content.value;" />
<input type="button" value="Update"
onclick="theElement.innerHTML =
document.my_form.content.value;" />
</form>
```

The `innerHTML` method we use to insert text.

When you click the “Send” button, a document will be added to the text of the html page of the electronic learning resource in the LMS.

When you click the “Update” button, the document in the text of the html page in the LMS will be updated to the latest version of this document on the OneDrive server.

4 Testing the model in the educational process

As an example, we consider a typical curriculum task.

One of the tasks included in the section “Navigational calculations” of the course of information technologies for navigators is the task of calculating the parameters of a large circle arc. Without going into details of navigational concepts, we note only for clarity that the orthodromy (the arc of the large circle) as the shortest distance between two points on the earth's sphere is a curve facing (on the map in the Mercator projection) the convexity to the nearest pole.

We give the calculation formulas of the problem.

Navigation along the arc of a large circle (orthodrome length):

$$S_{opt} = \arccos(\sin \varphi_H \cdot \sin \varphi_K + \cos \varphi_H \cdot \cos \varphi_K \cdot \cos(\lambda_K - \lambda_H)),$$

where $\varphi_H, \varphi_K, \lambda_K, \lambda_H$ – coordinates (latitude and longitude) of the starting and ending points. The latitudes of the intermediate points of the arc of a large circle for drawing on the Mercator map can be found by the formula:

$$\varphi_i = \arctg \frac{\sin(\lambda_i - \lambda_0)}{\operatorname{tg} K_0}$$

where λ_i is the longitude of the intermediate point, λ_0 is the longitude of the point of intersection of the equator with the orthodrome, K_0 is the angle between the meridian and the orthodromy at the point of intersection of the equator.

$$\lambda_0 = \frac{\lambda_H + \lambda_K}{2} - \arctg \left[\frac{\sin(\varphi_H + \varphi_K) \cdot \operatorname{tg} \frac{\lambda_K - \lambda_H}{2}}{\sin(\varphi_K - \varphi_H)} \right], \quad K_0 = \arctg \frac{\sin(\lambda_H - \lambda_0)}{\operatorname{tg} \varphi_H}.$$

The initial data of the task are the coordinates (longitude and latitude) of the departure point and the point of arrival of the vessel. As an example, consider: $\varphi_A = 47056 / N, \lambda_A = 5023 / W$ (latitude and longitude of the departure point); $\varphi_B = 11040 / N; \lambda_B = 58036 / W$ (latitude and longitude of the point of arrival). The calculation procedure, obviously, is as follows: first, the distance traveled along the orthodromy is calculated, then λ_0, K_0 , and finally, the latitude of the intermediate points of the arc of the large circle φ_i .

The calculation results using MS Excel are presented in Fig. 4

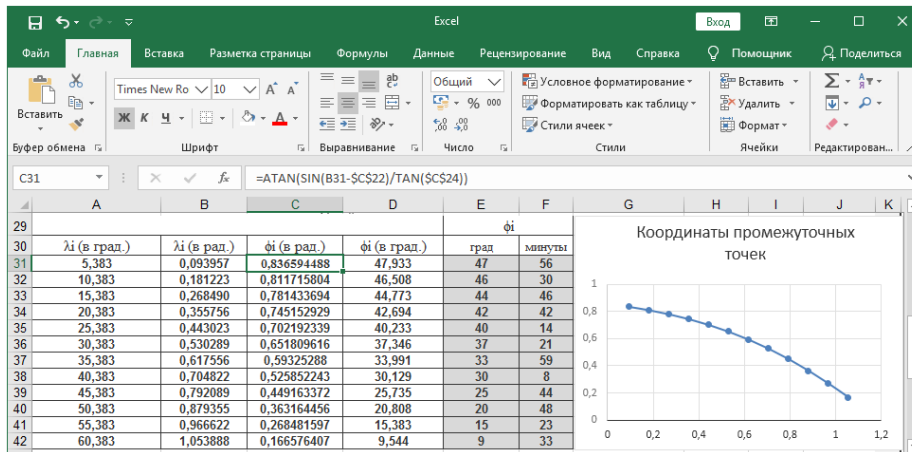


Fig. 4. Calculation of the parameters of the arc of a large circle with MS Excel.

Obviously, the result obtained is correct, since the values of intermediate latitudes are in the interval $[\varphi_H, \varphi_K]$. We construct the trajectory of the ship along the coordinates (longitude and latitude), the type of diagram is “point”.

Perform a similar calculation using the OneDrive cloud service. The calculation results with are presented in Fig. 5.

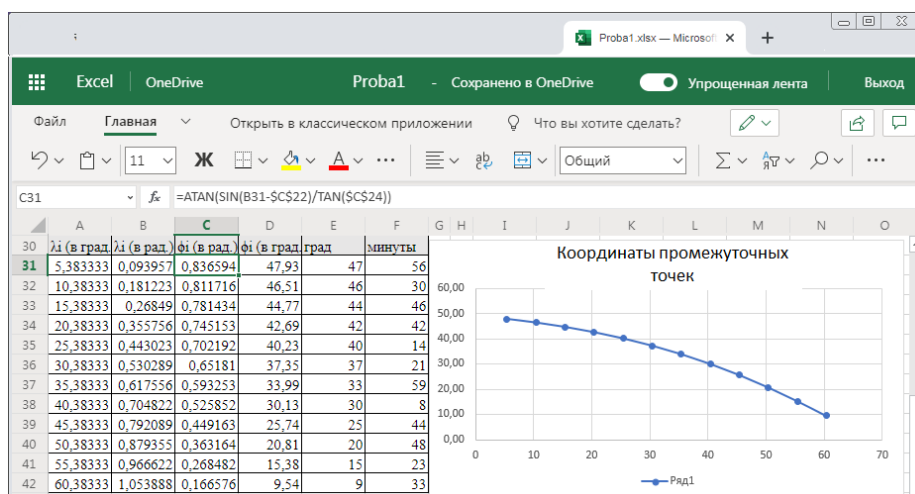


Fig. 5. Calculation of the parameters of the arc of a large circle with OneDrive.

The considered problem is a clear example of how important it is for the future navigator to be able to understand analytical formulas, conduct calculations, and analyze the result. Incorrect calculations can lead to negative consequences. Suffice it to say that the error in calculating the position of the vessel by only one degree leads to a discrepancy of 60 miles.

Pay attention to the fact that the calculation results are presented by two similar screenshots. In Fig. 4 - a screenshot of the calculation performed in standard MS Excel, in Fig. 5 – the same calculation, however, performed using the OneDrive cloud service.

Excel on the Internet is a web application that you can use to view and edit Excel workbooks in a browser. When editing in a browser, you can change data, enter and edit formulas, create tables and diagrams and apply basic formatting options in a spreadsheet. Workbooks and spreadsheets look almost the same in Excel on the Internet and familiar MS Excel. Many MS Excel functions are available in the Excel cloud service, but not all functions are supported or work in exactly the same way. But at the same time, the OneDrive Excel functions are quite enough so that the navigator can perform all the necessary calculations and arrange ship documentation.

Excel cloud service allows you to:

- use Excel functionality and features in a Web environment;
- perform work anywhere in the world, regardless of whether the office programs are installed on a computer or gadget. To access spreadsheets, you only need a browser and Internet access;
- perform work in projects with colleagues regardless of their version of Excel.

For simultaneous collaboration with other users in the same workbook, you can provide access to the book if there are spreadsheets on which you want to enter data, for example, a group project, or a registration spreadsheet. All that needs to be done is to create a separate folder for workbooks to which you need to share.

Among the obvious advantages of "cloud" Excel, you should definitely pay attention to some points. The main, in our point of view, is the following. During the period of study at the university, the cadet is provided with all the opportunities for acquiring skills for performing calculations of any complexity. He masters the methodology of structuring spreadsheets, using built-in functions and modules, building mathematical models of technological processes that can take place during the performance of professional duties on board a ship. A comparative analysis of spreadsheets showed that the ability to work in MS Excel, knowledge of the properties of built-in functions, the principles of filling their ranges will greatly facilitate and speed up the transition to OneDrive Excel.

5 Prospects for the use of cloud services in the educational process and on ship

We applied an expert method to assess the prospects of using cloud services in the educational process and on ship. Ten experienced teachers and sailors of Kherson State Maritime Academy were interviewed. Experts assessed the prospects for using cloud services in educational proses and on ship. For evaluation, a five-point Likert's system was chosen. Table 1 shows the results of the evaluation of indicators.

Table 1. Expert assessment of using cloud services in the educational process and on ship.

#	Evaluation Options	Grade
1	Compliance with the training program	3,9
2	Compliance with the requirements of the register of international maritime organizations of Ukraine and STCW	4,2
3	Expediency and prospects of using cloud services tables in the educational process	4,1
4	Expediency and prospects of using cloud services tables in the professional work of a sailor	4,6
5	The scientific feasibility of using a cloud electronic resource	3,8
6	Convenience of use during classes	3,3
7	Characteristics of ease of use in calculations and documentation on ship	4,5
8	Exchange of information between users of the program executed in the cloud service tables on ships	4,2
9	Compliance with a unified methodology	3,5
10	I plan to use cloud services spreadsheets in my professional work	3,9

The results of expert's assessment showed on Fig. 6.

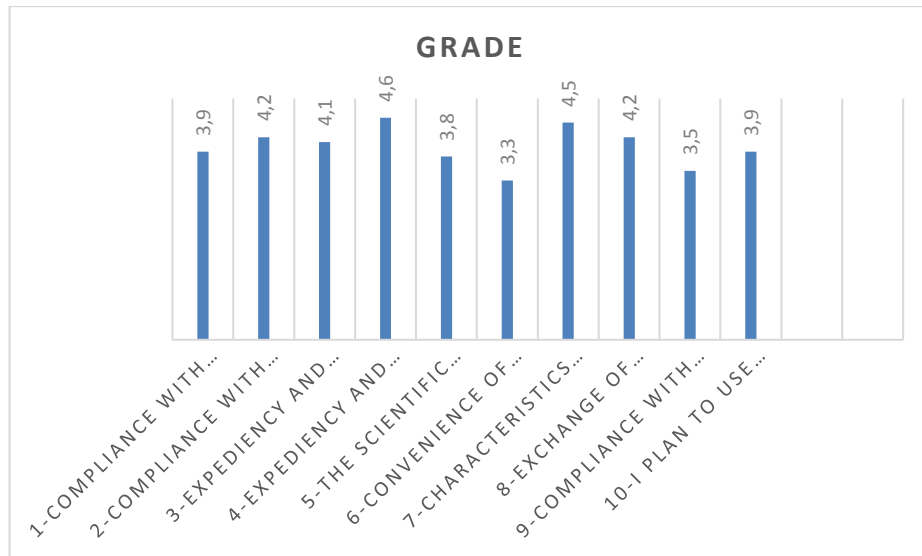


Fig. 6. Expert assessment of using cloud services in the educational process and on ship.

An expert assessment of the quality and prospects of using training resources can be considered sufficiently reliable only if the expert evaluations are in good agreement. Therefore, statistical processing of the results of expert evaluations should include an analysis of the consensus of experts. The Concordance method is used to assess the degree of consensus of experts on options for assessment [16].

The results of the expert survey are presented in Table 2.

Table 2. Expert data on assessment of using cloud services in the educational process and on ship.

Exp ert	Evaluation Options									
	#1	#2	#3	#4	#5	#6	#7	#8	#9	#10
1	9	8	3	4	5	2	6	7	10	1
2	8	9	2	5	4	3	6	5	10	1
3	10	9	3	4	6	2	5	7	8	1
4	10	7	2	4	5	3	8	6	9	1
5	10	9	2	3	4	5	7	8	6	1
6	9	10	3	2	5	4	6	8	7	1
7	7	10	2	5	4	3	6	8	9	1
8	8	10	3	2	6	9	5	4	7	1
9	9	10	4	5	8	2	3	7	6	1
10	9	8	5	4	10	2	3	6	7	1

Δ_i	34	35	-26	-17	2	-20	0	11	24	-45
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Concordance coefficient W is calculated according to the formula proposed by Kendall [16]

$$W = \frac{12S}{m^2(n^3 - n)} \quad (1)$$

Here $S = \sum_{i=1}^n \Delta_i^2 = \sum_{i=1}^n \left\{ \sum_{j=1}^m x_{ij} - \frac{1}{2} m(n+1) \right\}^2$, m – number of experts, n – the number of objects of examination, x_{ij} – assessment of the i -object by j -expert. Coefficient of concordance may vary between 0 and 1. If $W = 1$, all experts gave the same evaluations for all objects, if $W = 0$, the evaluations of experts are not coordinated.

Using the formula (1) calculated coefficient $W = 0,78$ is significantly different from zero, so we can assume that among experts there is objective concordance. Given that the value of $m(n-1)W$ is distributed according to χ^2 with $(n-1)$ is the degree of freedom, then $\chi_w^2 = \frac{12S}{m \cdot n \cdot (n+1)} = 70,6$. Comparing this value with the tabulated

value χ_T^2 for $n-1 = 9$ degree of freedom and significance level $\alpha = 0,05$, we find $\chi_w^2 = 70,6 > \chi_T^2 = 16,9$. Therefore, the hypothesis of consistency of expert evaluations confirmed according to Pearson.

Thus, the results of a pedagogical experiment can be taken as a basis for the design and creation of learning resources using cloud services.

6 Conclusion and future work

The article analyzes the cloud services Excel Reader.NET, Excel Viewer 2.0, shared hosting Amazon, TheRackSpace, Google, Microsoft, iCloud, SugarSync, Dropbox, Joyent, GoGrid, Terremark, Savvis, Verizon, NewServers for processing Excel documents. The analysis showed that cloud services can be used to display the contents of MS Office documents in the form of html text pages of electronic training resources.

The comparative characteristic of cloud services from Google and Microsoft is carried out. The choice of the OneDrive Office Online cloud service for implementation in the distance learning system "Moodle KMA" and "Kherson Virtual University" was justified.

A model of the process of creating, editing and implementing Excel documents in the distance learning system "Kherson Virtual University" using the Microsoft Excel Web App cloud service was built.

The functional properties, as well as features of the development of the software module "ExcelReader" are described.

An expert method for assessing the quality of the use of cloud services in the educational process and on the ship showed its good perspective.

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Augmented and Virtual Reality Technologies in Teacher Retraining

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Abstract. Research goal: theoretical justification for the use of augmented and virtual reality technologies in the educational process and the development of a blended course "Using the technologies of augmented and virtual reality in the practice of modern educational institutions" for retraining teachers. Research objectives: to determine the role and place of augmented and virtual reality technologies in the educational process and their use in teacher retraining for the formation of professional competence. Object of research: the formation of professional competencies of teachers in the retraining process. Subject of research: augmented and virtual reality technologies as a component of the school educational environment. Used research methods: theoretical methods containing analysis of scientific sources; empirical methods of interviewing and questioning teachers. Research results: analysis of scientific publications allows us to define the concept of augmented and virtual reality, its types, directions of using augmented and virtual reality in education, examples of its application in the educational process. The developed course "Using the technologies of augmented and virtual reality in the practice of modern educational institutions" for the retraining of teachers allows the formation of professional information and communication technologies competencies of teachers. Main conclusions: the introduction of virtual and augmented reality technologies in the educational process increases the effectiveness of training, promotes the development of logical thinking of students and increases the level of motivation of participants in the educational process.

Keywords: Augmented Reality, Virtual Reality, AR, VR, Blended Course, Technology, Teacher Retraining, Professional Competences.

1 Introduction

Technology has been growing fast and noticeably influencing different aspects of life such as education. Studies have revealed that Augmented Reality (AR) and Virtual Reality (VR) have strong potentials for helping students to improve their skills and

knowledge. In fact, bridging AR/VR and education can bring teaching and learning experiences in an attractive and effective way [1].

Augmented reality (AR) is an interactive experience of a real-world environment where the objects that reside in the real-world are "augmented" by computer generated perceptual information, sometimes across multiple sensory modalities, including visual, auditory, haptic, somatosensory, and olfactory [2].

AR allows combining and superimposing real objects with information and with virtual objects. Azuma defines an AR as a system to have the following properties:

- combines real and virtual objects in a real environment;
- runs interactively, and in real time; and
- registers (aligns) real and virtual objects with each other.

At the same time, the augmented information may not be limited to the sense of sight but may also be applied to all senses, such as hearing, smell and touch [3].

Supporting a variety of ways of presenting, acting, and many ways to engage students in the learning process makes AR a promising educational strategy.

Virtual reality (VR) is a popular information technology (IT) area that provides an indirect experience by creating a virtual space that interacts with the human sensory systems and overcomes spatial and physical constraints of the real world (Electronics and Telecommunications Research Institute (ETRI), 2001)

According to research in USA almost 80% of teachers have access to virtual reality devices, but only 6.87% use them regularly in the educational process. Wherein 97% of students would like to study a VR course. [4].

Mixed reality (MR) is the merging of real and virtual worlds to produce new environments and visualizations, where physical and digital objects co-exist and interact in real time. Mixed reality does not exclusively take place in either the physical or virtual world, but is a hybrid of reality and virtual reality, encompassing both augmented reality and augmented virtuality via immersive technology [5].

What is XR? XR – often referred to as “extended reality” – includes virtual reality (VR), augmented reality (AR), mixed reality (MR), and similar means of immersion.

Areas of AR and VR application in education is depicted in Fig.2.



Fig. 1. Applications of AR and VR in E-learning [6]

In 2020, in Europe, the total production value of the XR industry should reach €15-34 billion, and the number of direct and indirect jobs 225,000-480,000 [7].

The vast majority – 86 percent – of respondents to the 2019 Augmented and Virtual Reality Survey Report agreed that by 2025, XR technologies will be as ubiquitous as mobile devices.

2 Related Work

A brief overview of the history of the development of VR and AR technologies and their use in education is presented in [8]. In these works, the authors explore the concept of Virtual and Augmented reality, its history and set out the ontological difference between virtuality, possibility and actuality.

World review of using AR and VR in education is published by Pellas, Fotaris, Kazanidis [9].

Studies have shown that with the rapid adoption of technological innovations and increased investment by large companies such as Apple, Facebook, Google, Samsung and Magic Leap to improve the availability of AR and VR technologies, educational institutions will benefit from the opportunity to conduct training in virtual environments. The possibilities of virtual technologies to overcome the boundaries of formal education are demonstrated [10].

Jaime Donally, an educational consultant and author of *Learning Transported: Augmented, Virtual and Mixed Reality for All Classrooms*, pays attention, that it's important for educators to have a plan and purpose for introducing XR in the classroom. The most important part of selecting what immersive technology to deploy, she says, is “defining goals and expectations for how mixed reality integration will benefit classroom instruction.” [11].

Issues of the impact of augmented reality technologies on increasing students' motivation level are considered in [12].

Ukrainian researches Mariya P. Shyshkina, Serhiy O. Semerikov, Viacheslav V. Osadchyi, Kateryna P. Osadcha, Oleksandr Yu. Burov, Svitlana H. Lytvynova, Andrii M. Striuk and others address issues implementation Augmented reality in science education and applying Augmented reality in professional training and retraining [13, 14].

EU Research and Innovation programmes aimed at providing breakthroughs, discoveries, and world-firsts pay particular attention to projects related to augmented and virtual reality technologies.

Erasmus+ project entitled VR@School - Future schools using the power of Virtual and Augmented Reality for education and training in the classroom was written and coordinated by Liceul Teoretic de Informatica "Grigore Moisil" (Romania) and involves Pixel in the transnational partnership. The project was funded by the European Commission in the framework of the Erasmus+ Programme, KA2 - Strategic Partnership for School Education. The VR@School project aims at supporting Virtual Reality as a teaching methodology, which helps students feel immersed in an experience, gripping their imagination and stimulating thought in ways not possible with traditional books, pictures or videos, and facilitates a far higher level of knowledge retention [15].

The main objectives XR4ALL as an initiative of the European Commission to strengthen the European XR industry are to create a pan-European (XR-tech) community, to discover existing EU XR technology, to develop a research agenda, to award grants for innovative technology projects, to increase investments and tech transfers to help products reach market [16].

A large number of international scientific and practical conferences (AR & VR World 2020, VRDAYS EUROPE 2020, EuroVR 2019, IEEE VR, XRDC, AREdu and etc.) confirms the relevance of the introduction of augmented and virtual reality technologies in education and the interest of the scientific community in these innovative problems.

In Kherson State University and in Communal Higher Educational Establishment "Kherson Academy of Continuing Education" of Kherson Regional Council there is an extending experience in teachers' trainings [17, 18].

3 Problem Setting

In modern conditions of the development of technologies and changes in public life, one of the most important components of education is the development of information competence.

The issues of development of information competency of teachers are of special importance and urgency because the problem of development of information educational environment and the possibility of its use in professional activity is very important.

The purpose of the article is the theoretical justification for the use of augmented and virtual reality technologies in the educational process and the development of a blended course “Using the technologies of augmented and virtual reality in the practice of modern educational institutions” for retraining teachers.

Tasks:

- Analyze of main features and benefits of technologies of augmented and virtual reality;
- Find the attitudes of teachers to use augmented and virtual reality in education;
- Development of a blended course “Using the technologies of augmented and virtual reality in the practice of modern educational institutions” for retraining teachers;
- Implementation of the blended course “Using the technologies of augmented and virtual reality in the practice of modern educational institutions” in order to form the professional competencies of teachers in the field of information and communication technologies.

4 Development of a blended course “Using the technologies of augmented and virtual reality in the practice of modern educational institutions” for retraining teachers

In order to increase the level of professional information and communication technologies competencies of teachers at the Communal Higher Educational Establishment "Kherson Academy of Continuing Education" of Kherson Regional Council and at Kherson State University the blended course «Using the technologies of augmented and virtual reality in the practice of modern educational institutions» was developed.

The objective of the blended course is to prepare teachers in the system of continuous pedagogical education for the use of augmented and virtual reality technologies in everyday and professional activities, generalization, systematization and exchange of experience, raising the level of their professional mastery using digital technologies.

The target group of the course is teachers of different categories and specialties who see the potential of AR and VR technologies in education, striving by modern technology to minimize the digital divide between teacher and student, to improve the quality of education and the motivation of objects of educational activity.

The blended course «Using the technologies of virtual and augmented reality in the practice of modern educational institutions» is aimed at solving the following problems:

- disclosing the educational capabilities of augmented and virtual reality technologies;
- assistance to the quality development of the information educational environment of teachers;
- stimulation of the productive activities of teachers and students, oriented toward creative self-realization by means of augmented and virtual reality technologies;

- popularization of augmented reality as a factor that contributes to the generalization of experience, the dissemination of copyright developments, professional growth and development of teachers;
- effective use of modern digital technologies for educational purposes;
- increasing the interest of teachers in the active use of augmented and virtual reality to solve the problems of modernization of education;
- improving the effectiveness and efficiency of professional teaching activities;
- dissemination of advanced pedagogical experience.

As a result of studying the course, the teacher should know:

- the concept, types and possibilities of using augmented and virtual reality technologies in the professional activities of teachers;
- normative documents defining state policy in the field of information competence of teachers and students, as well as the basics of information security;
- types and features of the functioning of finished projects of augmented reality (Futurio, Quiver, Elements 4D, Octagon series cards, etc.);
- the purpose and basic functionality of the platforms for creating augmented reality Futurio, Quiver, BlippAr, Wallame;
- programs and algorithms for creating marker augmented reality;
- methodological features of using augmented reality technology in the context of ordinary, flipped, blended and distance learning;
- methodology for introducing elements of augmented reality in the professional activity of a teacher.

As a result of studying the course, the teacher should be able to:

- apply ready-made augmented and virtual reality projects in education (Futurio, Quiver, Elements 4D, Octagon series cards, etc.);
- create augmented reality with the Wallame application tools and exchange messages in the real world with the help of augmented reality;
- create interactive maps of the area using the technology of augmented reality;
- create augmented reality scenes using the BlippAr application;
- apply augmented and virtual reality technologies in the organization of educational and extracurricular activities.

The program is based on the principles of scientific, systematic, accessibility; practical orientation, taking into account the experience of introducing courses on the study of digital technologies in educational institutions of various types, as well as the needs of students of continuing education courses, taking into account their professional and digital competencies.

Schema of blended course “Using the technologies of augmented and virtual reality in the practice of modern educational institutions” is depicted in Fig.2.

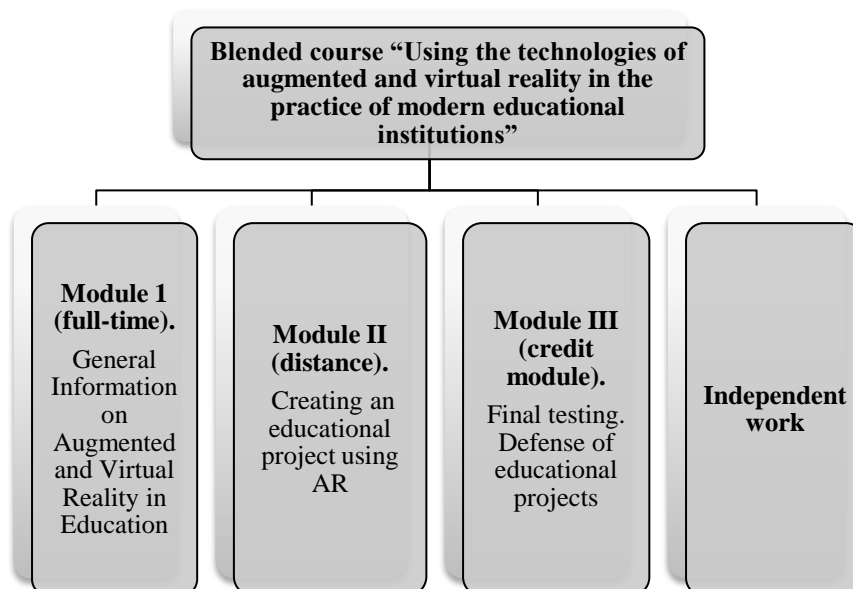


Fig. 2. Schema of blended course “Using the technologies of augmented and virtual reality in the practice of modern educational institutions”

The blended course program is designed for 36 hours, of which 6 hours are lecture classes, 16 - practical classes, 18 - independent work.

The program includes the following training modules: full-time module "General Information on Augmented and Virtual Reality in Education"; distance module "Creating an educational project using AR"; independent work; credit module (individual project of each teacher).

The program provides for training sessions with various forms of cooperation, involving the use of active innovative organizational forms, interactive methods and based on the use of digital technologies with a professional focus. This creates the conditions for the manifestation of initiatives for students, creativity, independent search, ensuring the appropriate level of professionalism of students, the ability to introduce the knowledge into the educational process of modern educational institutions.

The distribution hours of classroom work to lecture and practical is approximate and can be changed while maintaining the total number of hours.

A significant part of the study time is devoted to independent work.

The educational strategy of the course is also implemented by distance learning through online consultations and the implementation of individual practical tasks; independent study by students of the training material recommended by the teachers of the course.

The training course is practice-oriented, and therefore, the predominant part of the time is devoted to the practical work of teachers with augmented reality applications: modeling and designing of a training project, creation, design, filling, optimization, etc.

Tasks for independent work are focused on self-study of the course; adding your own information resources; search for ways to implement educational projects using augmented and virtual reality technologies in the context of the traditional educational process or the introduction of flipped learning and etc.

The thematic plan for studying the blended course is presented in table 1.

Table 1. Thematic plan for studying the blended course «Using the technologies of virtual and augmented reality in the practice of modern educational institutions»

№ п/п	Lesson topic	Total hours	Of them		
			Lecture	Practice	Inde- pend- ent work
Module I (full-time). General Information on Augmented and Virtual Reality in Education		20	4	6	10
1.	Introductory questionnaire. The history of the emergence and development of augmented and virtual reality		1	1	
2.	An introduction to augmented and virtual reality. <i>Practical work № 1. Applications for Augmented and Virtual Reality</i>		1	1	2
3.	Application of augmented reality technology in education. <i>Practical work № 2. AR and VR in education. Work with ready-made augmented reality projects</i>		1	2	4
4.	Introduction to the applications of creation of augmented reality in education. <i>Practical work № 3. Creation of AR and VR projects</i>		1	2	4
Module II (distance). Creating an educational project using AR		14		6	8
1.	Wallame application and its fields of using in education. <i>Practical work № 4. Create an interactive map with the Wallame app.</i>			2	4
2.	BlippAr app. <i>Practical work № 5. Creating cards with elements of</i>			4	4

	<i>augmented reality using the BlippAr application.</i>				
Module III (credit module).	2		2		
Total	36	4	14		18

The curriculum of the blended course “Using the technologies of augmented and virtual reality in the practice of modern educational institutions” provides for the creation of individual and collective creative projects that have prospects for implementation in Ukrainian schools based on their own pedagogical experience.

5 Setting up the Pedagogical Experiment

The course was held for 198 students of continuing education courses (teachers of the Kherson region, Ukraine). There were 43 (21.7%) teachers of mathematics and computer science, 35 (17.7%) primary school teachers, 28 (14.1%) Ukrainian language and literature teachers, 22 (11.1%) biology teachers, 21 (10.6%) physics teachers, 19 (9.6%) chemistry teachers, 17 (8.6%) history teachers. The remaining categories did not exceed 2%.

To identify teachers' readiness to support and implement augmented and virtual reality technologies, the questionnaire was developed in Google Forms (Fig.3).

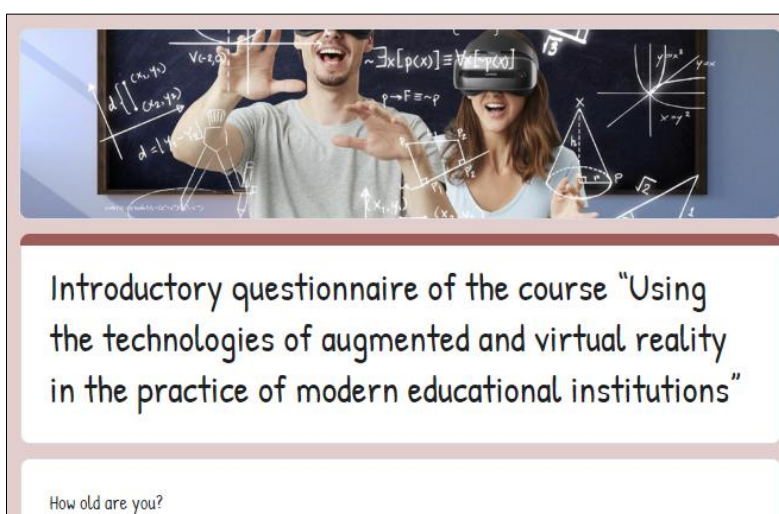


Fig. 3. Introductory questionnaire of the course “Using the technologies of augmented and virtual reality in the practice of modern educational institutions”

The questionnaire survey showed that the overwhelming majority of teachers own digital technologies at the basic (35.4%) and higher than the basic (30.3%) levels. However, it should be noted that there were 12 teachers (6.1%) who did not have the

skills to work with digital technologies. These are mainly teachers of philological disciplines of the older age.

Figure 4 shows the responses of teachers about the level of digital technology ownership.

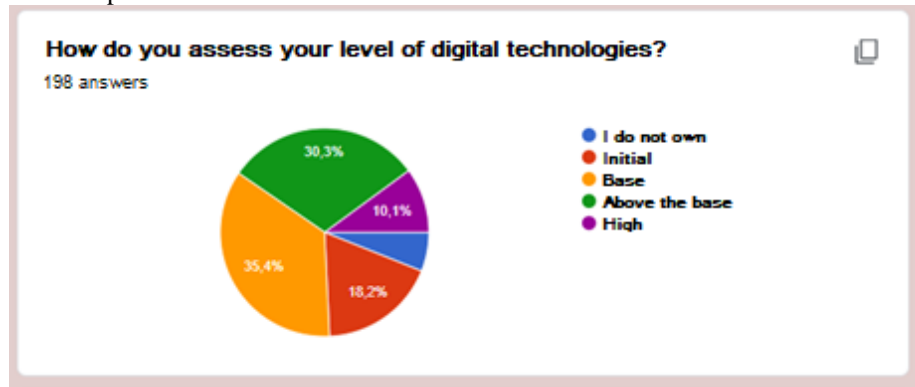


Fig. 4. Responses of teachers about the level of digital technology ownership.

A sufficiently large number of teachers have skills of using information and communication technologies in the educational process, as were show answers presented in Figure 4.

The level of awareness of teachers about augmented and virtual reality technologies turned out to be quite high. This is evidenced by the answers presented in Fig. 5.

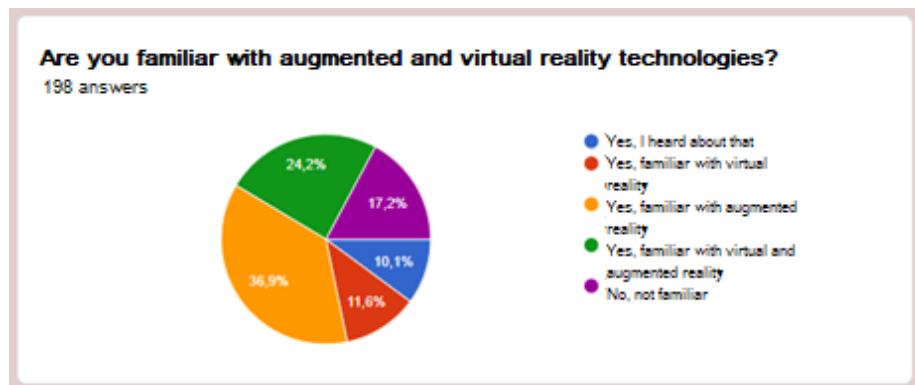


Fig. 5. Answers to teacher awareness of AR/VR technology question

24.2% of respondents have an idea of both technologies, and also 48.5% are familiar with at least one of them. It should be noted that augmented reality technology is more popular among teachers than virtual reality technology. Among the main reasons for this: the prevalence of smartphones and tablets. lack of need for additional equipment, increasing distribution of software with support for augmented reality.

The results of a survey of teachers showed a high level of motivation to study the course “Using the technologies of augmented and virtual reality in the practice of modern educational institutions” for the development of digital competencies with the purpose the application of innovative technologies in educational process.

For different groups of teachers, topics of projects using augmented reality were selected that correspond to the disciplines they teach.

So, for teachers of elementary school, environmental studies, astronomy, it was proposed to use ready-made augmented reality projects based on Octagon Studio's live instruction cards. Flash cards Space 4D + allow you to study the properties of space objects. The application scans printed space maps and allows you to watch how space comes to life. Among the cards of the collection are: the Solar system, space objects, planets, satellites, etc.

Examples of the results of practical work of teachers with educational cards Space 4D + with augmented reality depicted in Fig. 6.

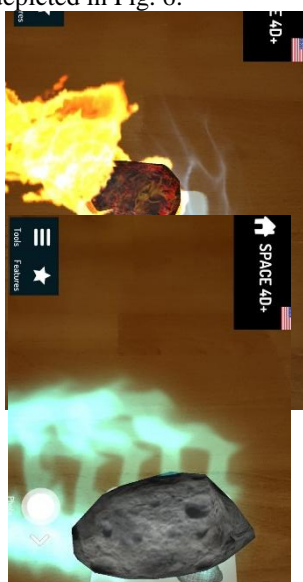


Fig. 6. Examples of using Space 4D + training augmented reality cards to study the properties of space objects

The use of such cards in the lessons can significantly increase the level of students' motivation and the degree of perception of the material.

Among similar applications, Octagon Studio also includes Humanoid 4D + for studying the structure of the human body, Octaland 4D (for studying professions), Animal 4D + (for studying animals), etc.

Practical work по изучению инструмента разработки учебных объектов дополненной реальности мобильного приложения VlppAR и веб-сервиса VlppBuilder предполагает создание интерактивных карточек.

An example of using augmented reality based on the development of interactive cards by teachers of mathematics is shown in Figure 7.

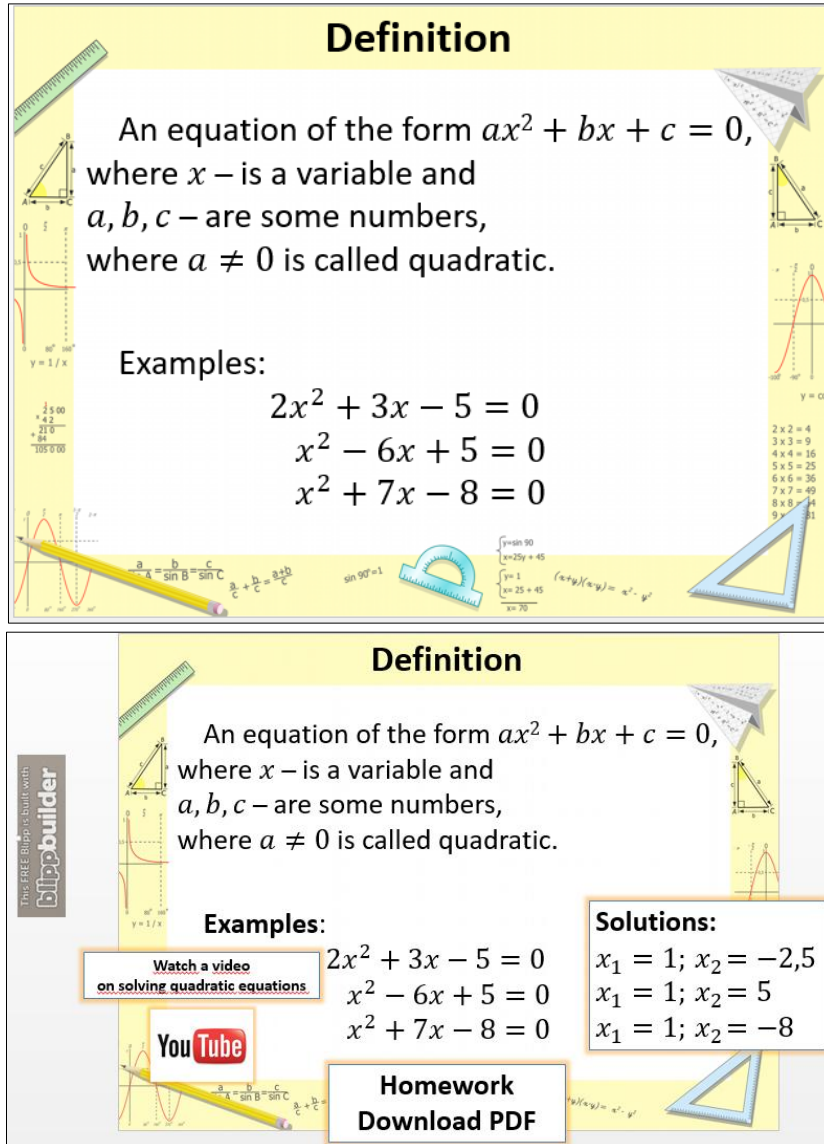


Fig. 7. An example of a project with elements of augmented reality, completed by teachers of mathematics, created using the BlippAr application

When creating a didactic card, the model of organizing access to educational objects of augmented reality using markers, mobile devices and augmented reality browsers, proposed in [19], is used. A card with a math assignment is marked with a special marker. To recognize the marker, a mobile device with a camera and an augmented reality browser installed is used. Once in the camera field, the marker is recognized by the program and the augmented reality scene is displayed on the device

screen. In this scene, elements such as an image, text (for example, with answers for self-testing), video (with an explanation of theoretical material or an algorithm for solving problems of this type), a three-dimensional model, etc. are superimposed on the image received from the device's camera. The interactive scene suggests the possibility of interacting with the user based on the script [19].

The task of the final control is to check the teachers' understanding of the material of the course as a whole, the logic and relationships between the individual sections, the ability to creatively use the accumulated knowledge, the ability to form their own attitude to a particular problem of academic discipline and apply augmented and virtual reality technologies in the educational process.

The final test provides for 2 groups of questions: questions that verify the degree to which teachers master the course material; questions that test the practical skills of teachers in using augmented and virtual reality applications.

As a final work, students are invited to develop a project that provides for the creation of an interactive laptop with elements of augmented reality and to develop a lesson summary using augmented reality technology within the chosen discipline.

6 Conclusions and Outlook

Analysis of scientific publications allows us to define the concept of augmented and virtual reality, its types, directions of using augmented and virtual reality in education, examples of its application in the educational process. The developed course "Using the technologies of augmented and virtual reality in the practice of modern educational institutions" for the retraining of teachers allows the formation of professional information and communication technologies competencies of teachers.

Examples of using augmented reality applications in the study of mathematics and astronomy are considered.

The results of the pedagogical experiment showed a high level of motivation of teachers of elementary and secondary schools to study and use augmented reality technologies in the educational process.

The introduction of virtual and augmented reality technologies in the educational process increases the effectiveness of training, promotes the development of logical thinking of students and increases the level of motivation of participants in the educational process.

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Exploring Student Uses of Mobile Technologies in University Classrooms: Audience Response Systems and Development of Multimedia

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Abstract. The research is aimed at theoretical substantiation, development and experimental verification of methods of applying mobile technologies by university students. The research objective implies adapting audience response systems and mobile tools of multimedia development to be used in the classroom environment at universities. The research object is application of mobile ICT to the training process. The research subject is methods of applying audience response systems and mobile tools to conducting practical classes at the university. There are analyzed Ukrainian and foreign researches into the issues of mobile ICT application to the university students training. The authors have developed methods of applying audience response systems by taking Plickers as an example and mobile tools of multimedia development through using augmented reality tools. There is comparative assessment of functionality of audience response systems and mobile tools of developing multimedia with augmented reality. Efficiency of the developed technology is experimentally verified and confirmed.

Keywords: mobile technologies, audience response systems, development of multimedia.

1 Introduction

Application of mobile technologies was the issue for investigation in works by Mmaki

Elisabeth Jantjies [5], and Faranak Fotouhi-Ghazvini [6] (in teaching languages), Serhiy O. Semerikov [7] (in teaching Computer Sciences), Ahmad Abu-Al-Aish [8], Sakina Sofia Baharom [9], Peter W. Bird [10], Christopher Billington [11], Esra A. Wali [12], Jonathan J. Trinder [13] and Marian Hepburn [14] (in the tertiary education system), Yinjuan Shao [15] (in open education), Victoria Jotham [16] and Nee Nee Chan [17] (in everyday life).

Application of audience response systems (ARS) is described in [1], where the authors indicate that tests can be designed directly by tutors, and delivered via a network. Evaluation of the tests suggests that immediate automated testing is preferred by students compared to a traditional written test. There is evidence that the tool improves the IT skills of its users, whereas a traditional written test has no such beneficial effect.

Jenifer Santos, Luisa Parody, Manuel Ceballos, María C. Alfaro and Luis A. Trujillo-Cayado [2] described effectiveness of mobile devices as ARS in the chemistry laboratory classroom. Their paper concretizes pedagogical innovation involving smartphone technology and offers teachers the opportunity to create an environment of engaging learning in laboratories. In this paper, the authors outline how to use Socratic Student Response by Mastery Connect, a variation of a real-time ARS. They hypothesized that using this application as an ARS can enhance learning and identify student knowledge gaps in chemistry laboratory classes. In order to explore the relationships among factors and the educational effectiveness of Socratic responses, they investigated the data from a graduate-level chemistry course students. Before and after laboratory classes, experimental groups completed an ARS quiz using Socratic application in their mobile devices. The results revealed that students felt that the method enhanced their learning process whereas teachers reported that it improved academic performance and the relationships between teachers and students.

The research by Sebastian Schlucker [3] contains a report on application of mobile devices in the classroom environment and substantiates the necessity of motivating and activating elements of lectures to make as many students participate and reflect as possible. It can be done by using surveys or quizzes answered anonymously on smartphones. Quizzes are also beneficial as a university teacher can learn something about their students and their learning progress.

Dylan M. Moorleghen, Naresh Oli, Alison J. Crowe, Justine S. Liepkalns, Casey J. Self, and Jennifer H. Doherty [4] researched into the impact of automated response systems on in-class cell phone use. Their paper reveals that cell phones have long been known as a potential distraction from attention intensive activities such as studying and driving. Many, however, consider the cell phone as a powerful tool to augment some of these same activities. ARS are a type of teaching tools that allows educators to poll audience members in real time. Increasingly, cell phones are being integrated into ARS to make them more versatile and affordable. As cell phones and other personal electronic devices (tablets, laptops) are becoming more common classroom learning tools, researchers sought to explore how student cell phone use is impacted by this change. Additionally, they studied how a student's seat location and how the time during a term impacts students' cell phone use. To measure student cell phone use during lectures, introductory biology classes were observed at the University of

Washington and it was recorded when students' cell phones were visible. The authors found that students sitting in the back of the room showed an increased likelihood of having a cell phone out. However, contrary to our expectations, students using personal device (cell phone) based polling technology were no more likely to be using cell phones during lectures than their peers using traditional ARS. The results suggest that the downsides of using cell phones as teaching tools may be limited.

2 Application of mobile ICT to training

2.1 Methods of applying audience response systems

Tools of monitoring, controlling and assessing academic results are some of mobile software ICT types.

While monitoring the maturity level of students' ICT competences according to the model in [25], there are applied various monitoring tools with the testing control of knowledge being a priority. ARS are tools for assessing students' academic results.

ARS are a variety of mobile software tools aimed to measure students' academic results that enables automatizing the process of current and final control through applying modern testing tools and intensifying students' learning due to:

- ensuring mobility, cost effectiveness (efficiency) and privacy of testing through developing and implementing the technology of storing and using a short-term session of transmitting test assignments from the Internet server by wireless connection means;
- solving the problem of constraints in terms of technical characteristics and distance differentiation of teachers' and students' computers during a testing session arrangement [18].

ARS aligning with this definition include ClassMarker, EasyTestMaker, Google Forms, iSpring QuizMaker, Kahoot!, MyTestXpro, Plickers, ProProfs, etc.

In our research, we distinguish the ARS Plickers as the one providing an opportunity to arrange a rapid feedback between a teacher and an academic group including individual students; conducting a mobile survey, in-class general questioning and instant control of students' attendance. This system is beneficial in terms of high efficiency as it is very time-consuming and availability of students' smartphones or computers is not obligatory as a teacher's mobile device will do.

Plickers can be used in various operating systems of fixed computers and mobile devices. The system is meant for up to 63 students tested simultaneously. The system is noted for instant scanning of students' responses by a teacher's mobile device. The system also enables viewing students' testing results (both of a group as a whole and each student separately) in the form of a table.

To work with Plickers, a university teacher should get registered on the site (<https://www.plickers.com/>) and compile a library of tests on a variety of subjects (Fig. 1).

The system enables creating an academic group list while testing (Fig. 2).

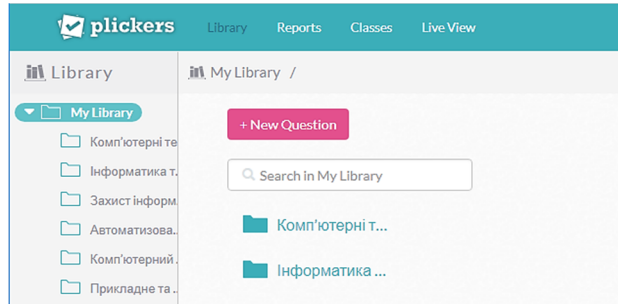


Fig. 1. The library of tests on Computer Sciences in the Plickers ARS

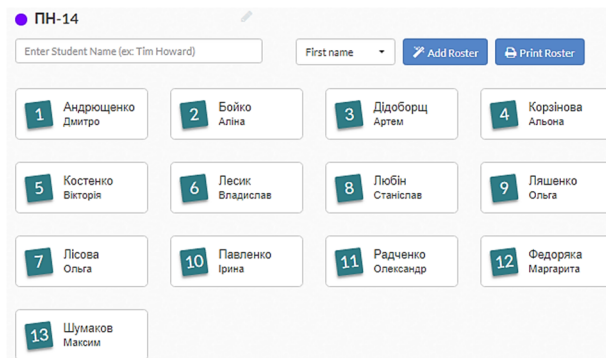


Fig. 2. The list of an academic group in the Plickers ARS

During testing, students are provided with cards with QR-codes (https://www.plickers.com/PlickersCards_2up.pdf) containing response options A, B, C, and D (Fig. 3). After reading a question, students raise a card with a chosen response scanned by a teacher's mobile device.

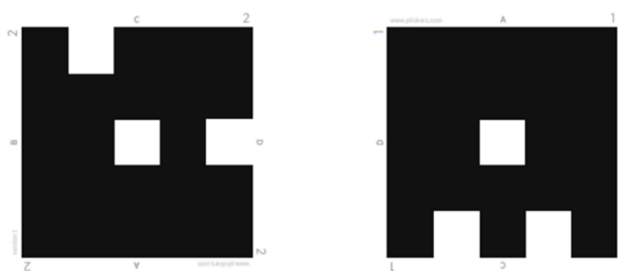


Fig. 3. Plickers cards with QR-codes

After scanning QR-codes of the cards, the data from the teacher's mobile device is transmitted to the Plickers cloud where they are processed and stored. Plickers enables either analysis of individual students' results or a general characteristic of a student group's statistics.

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To make a survey, a teacher uses the Plickers site in the section LiveView (Fig. 4), which has a special mode of viewing questions controlled by a mobile device.

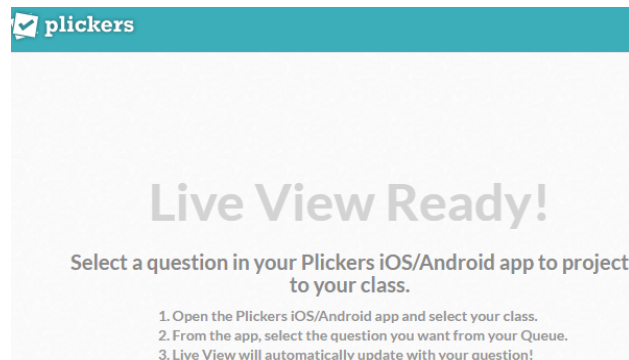


Fig. 4. The LiveView mode

To scan students' responses, you should open Plickers and choose an academic group on its main screen (Fig. 5).

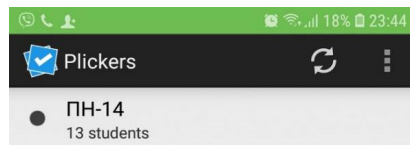


Fig. 5. The main page of the Plickers ARS

Students' use Plickers cards in Informatics class at Kryvyi Rih National University (Fig. 6).

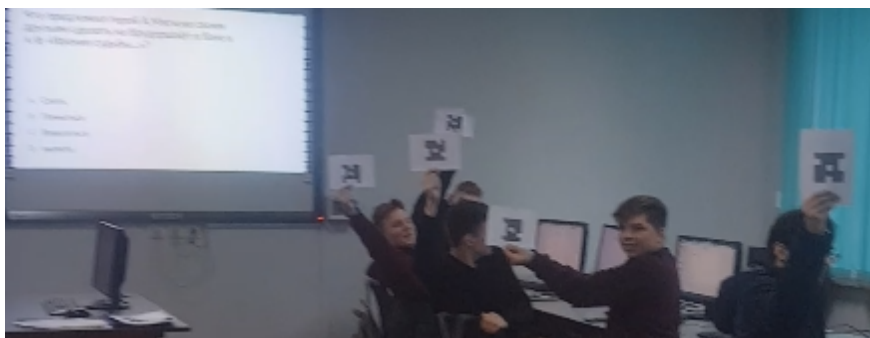


Fig. 6. Students' Plickers cards in class

Table 1 gives comparison of functionality of mobile ARS. Among various tools under analysis, attention should be paid to Plickers that enables combining of mobile device and augmented reality into a single multimedia environment.

Table 1. Assessment functionality of audience response systems

Features \ ARS	Class-Marker	Easy-Test-Maker	Google Forms	iSpring Quiz-Maker	Kahoot!	MyTestX-pro	Plickers	Pro-Prof
Assignment types								
choosing one of two contrary	+	+	+	+	+	+	+	+
choosing one of many	+	+	+	+	+	+	+	+
multiple-choice	+	+	+	+	+	+	-	+
relevance	+	+	+	+	+	+	+	+
open response	+	+	+	+	+	+	+	+
Others								
availability of a web-version	+	-	+	-	+	-	+	-
possible independent work	+	-	-	-	-	-	+	-
Ukrainian localization	-	-	+	-	-	-	-	-
iPhone OS and Android.	-	+	-	+	-	+	+	+
availability of full-scale free version	-	-	+	-	+	+	+	+
cloud storage	+	-	+	-	+	-	+	-
minimal requirements to a mobile device	+	-	-	-	+	-	+	-
Rating	9	6	9	6	9	7	10	7

2.2 Methods of applying mobile tools of multimedia development

Combination of various ways of data presentation is the core of the multimedia learning theory developed by Richard E. Mayer who distinguishes four cognitive processes – choice, arrangement, transformation and integration of data [19, p. 118]. Selected text and graphical data are processed separately first. Next, selected data are arranged into two separate models for word and graphical data. While being processed, word data can be transformed into graphical ones (for example, by building mental images) and vice versa (by using internal verbalization of images). To successfully accomplish

multimedia learning, both models should be integrated and associated with previously acquired knowledge [19].

According to Mayer [20], there are three basic approaches to presenting multimedia materials:

1. according to transmitting channels – by two or more devices (for example, a screen and speakers);
2. according to transmitting modes – text- and graphics-based (screen texts and animation);
3. according to perceptive modality – aural and visual (animation accompanied by narration).

Each of these approaches is relevant to a separate class of multimedia development tools: the first class (tools of video-data designing), the second class (presentation designing tools), and the third one (augmented reality tools including Augment, Blippar, Amazon Sumerian, Anatomy 4D, AR Flashcards Space Lite, AR Freedom Stories, AR-3D Science, Chromville, Elements 4D, HP Reveal, and Google Lens. With any approach applied, Mayer insists on the following principles of multimedia development to be guided by [20, p. 59–60]:

1. The multimedia principle: people learn by words and images better than by words only.
2. The space vicinity principle: people learn better when corresponding words and images go together and not far from each other on a page or screen.
3. The time adjacency principle: people learn better, when corresponding words and images go simultaneously and not in succession.
4. The coherence principle: people learn better, when irrelevant words, images and sounds are off and not on.
5. The modality principle: people learn better by using animation and narration than by animation and a screen text.
6. The excessiveness principle: people learn better by using animation and narration than by animation, narration and a screen text.
7. The personalization principle: people learn better, when words are presented in spoken language than in formal one.
8. The interactivity principle: people learn better, when they control the presentation pace.
9. The signalization principle: people learn better, when words contain markers on presentation arrangement.
10. The principle of individual distinctions: multimedia effects affect low-level students better than high-level ones. Multimedia effects are more powerful for highly professional students than for low-professional ones.

Observance of these principles enables us to declare that any system in compliance with them is a mobile tools of multimedia development.

Application of mobile tools of multimedia development allows increasing efficiency of controlling students' attention span and motivation.

Considering the fact that methods of using tools of designing videos and presentations are revealed in [22; 23; 24], it is more reasonable to deal with mobile tools of augmented reality development in this paper.

To arrange students' activity while studying Computer Technologies in Education, we apply the system Blippar [21], which enables multimedia projects of augmented reality to be implemented. Fig. 7 gives a generalized model of applying Blippar to professional training.

Blipp is a Blippar object containing the scene elements and a relevant marker. To create a Blippar object, you should select Create Blipp on the My Blipps menu or create a new project, which will contain this object (Fig. 9). The Blippar object can be created visually either by combining 3D objects and animation or by using JavaScript (Fig. 10). The visual method is the simplest.

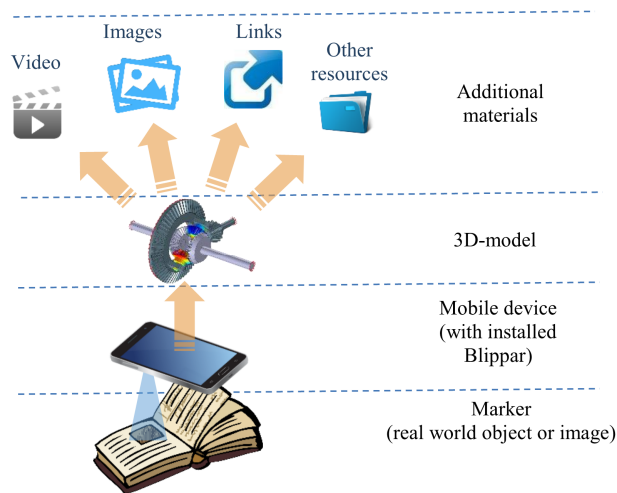


Fig. 7. The model of applying Blippar to professional training (according to [22])

Before performing a multimedia project with augmented reality in Blippar, one should get registered on their official site – <https://accounts.blippar.com/signup/free> (Fig. 8).

Fig. 8. Registration on the Blippar site

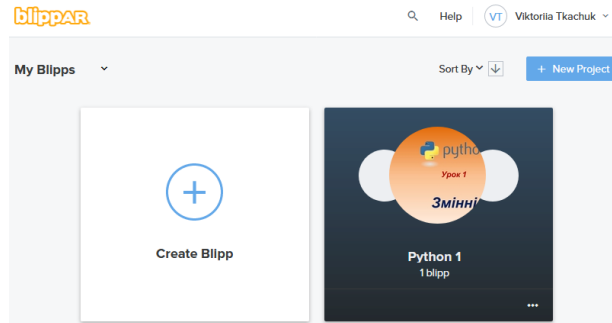


Fig. 9. Creation of the Blippar object (1)

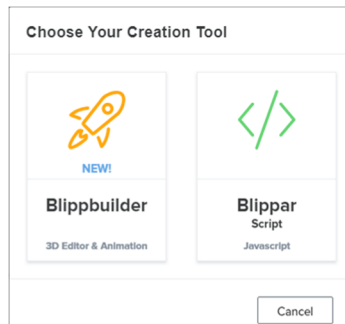


Fig. 10. Creation of the Blippar object (2)

The first step implies uploading or generating an image that will be used as a marker (Fig. 11).

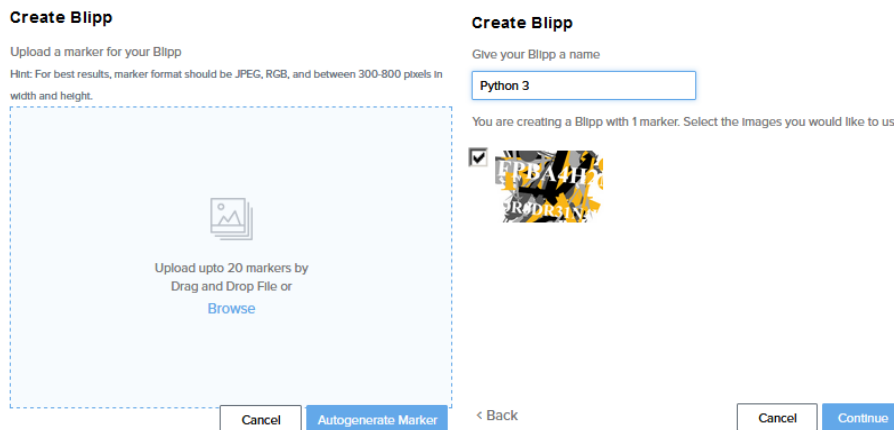


Fig. 11. Selecting a method of marker creation.

The second step involves creation of a scene by using the visual editor BlippBuilder (Fig. 12) to provide a user with panels Elements (simple geometrical 3D objects and text), “Widgets” and “Uploads” (to upload models in FBX format).

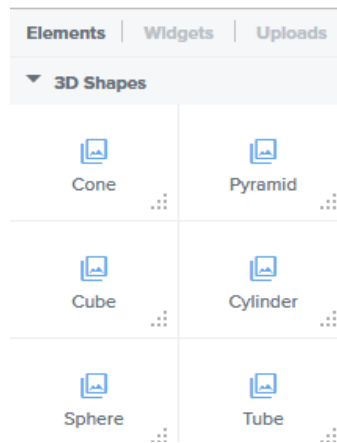


Fig. 12. Editing panels of BlippBuilder

In the editing box, one can add figures and text and activate or deactivate them in the menu, select a front, colour (select from the options or set colour by a number, for example #778899), transparency, size, position and rotation (Fig. 13), add external references, upload a video/audio, etc.

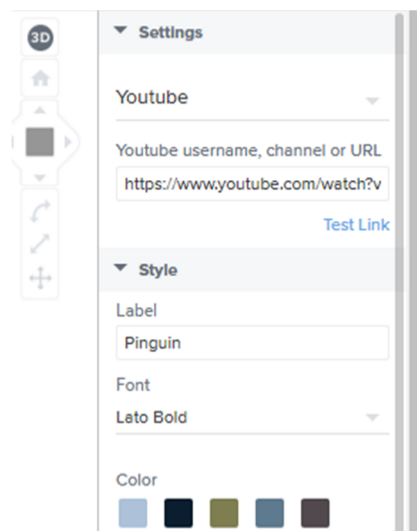


Fig. 13. Settings of Blippar scene elements

The third step involves viewing and demonstrating the Blippar object after completing

scene adjustment (Fig. 14).



Fig. 14. Preview/demonstration of the Blippar object

For each Blippar object, a unique code is generated that enables its viewing in the mobile device (Fig. 15). To view the Blippar object, one should download an augmented reality browser and enter the code of the Blippar object in its settings. After that, the Blippar browser will recognize the object marker and download the relevant scene.

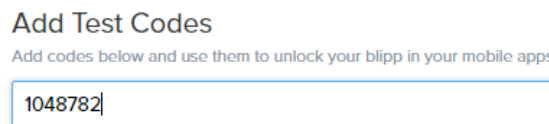


Fig. 15. The code for viewing the Blippar object

Fig. 16 shows the marker for Code 1048782 associated with the video-lesson *Changes in Python language*.



Fig. 16. The example of the marker of the Blippar object

Table 2 gives comparison of functionality of mobile tools with augmented reality. Among various tools under analysis, attention should be paid to Amazon Sumerian that enables combining tools of virtual and augmented reality into a single multimedia environment based on the web-browser supporting WebGL 2.0 and WebXR 1.0.

Table 2. Assessment of functionality of mobile tools of multimedia development with augmented reality

Mobile tools of Multimedia development with augmented reality	Amazon Sumerian	AR Flashcards Space	AR-3D Science	Augment	Blip-par	Chrom-ville	Elements 4D	HP Reve-al
Features								
Free dissemination	±	-	±	±	+	+	+	±
Development of one's own objects	+	+	-	+	+	-	-	+
Localization	-	-	-	-	-	-	-	-
Support of different platforms	+	-	-	+	+	+	+	+
Support of visual editing of objects	+	+	+	+	+	+	+	+
Support of various scientific fields	+	+	-	+	+	-	-	+
Rating	4,5	3	1,5	4,5	5	3	3	4,5

3 Results of experimental examination of the suggested methods

To examine the method, we determine criteria of efficiency of applying exploring student of mobile technologies in university classrooms, their indices and research methods (Table 3). Research based on experimental studies [23].

The pedagogical experiment was conducted at Kryvyi Rih National University, Kryvyi Rih State Pedagogical University, Kryvyi Rih College of National Aviation University, Kryvyi Rih Economic Institute of Kyiv National Economic University named after Vadym Hetman during of 2019-2020 educational year. Engineering Students were engaged in the experiment comprising 33 students of the experiment group and 32 students of the control group.

According to the 1st criteria, the number of students of the experiment group with high and medium motivation for training activity is larger than that of the control group by 9,94%. The 2nd criteria reveal the number of students of the experiment group with high and medium level of systematic accomplishment professional-oriented tasks which is larger than that of the control group by 12,97%. The 3rd criteria reveal the number of students of the experiment group with high and medium level of formation professional competencies which is larger than that of the control group by 13,07% (Table 4). After generalizing the results of the pedagogical experiment, we can conclude that the developed methods of applying exploring student of mobile technologies in university classroom are quite efficient, especially in terms of raising students' professional competencies. The total experiment results are given in Fig. 17.

Table 3. Criteria of efficiency of applying mobile technologies in university classrooms

Criterion of efficiency of applying mobile technologies		Index of efficiency of applying of mobile technologies in university classrooms	Levels of formation	Research methods
1st	Students' motivation for training activity	Availability of students' desire to study, perform complicated tasks; understanding of significance of studies	High; medium; low	Questionnaire "Motivation students' to use of mobile technologies in university classroom"
2nd	Systematic accomplishment professional-oriented tasks	Timely accomplishment of tasks	High; medium; low	Results of accomplishment tasks in setting time
3rd	Formation professional competencies	Availability of students' theoretical knowledge; a skill to independently accomplish tasks; objective assessment of students' own results; formed professional competencies	High; medium; low	Module test

Table 4. Experimental results

Criterion of efficiency of applying mobile technologies	Levels	Control group		Experiment group	
		number of people	%	number of people	%
Students' motivation for training activity	high	5	15,63	7	21,21
	medium	18	56,25	20	60,61
	low	9	28,13	6	18,18
	Total	32	100	33	100
Systematic accomplishment professional-oriented tasks	high	5	15,63	7	21,21
	medium	18	56,25	20	60,61
	low	9	28,13	6	18,18
	Total	32	100	33	100
Formation professional competencies	high	5	15,63	7	21,21
	medium	18	56,25	20	60,61
	low	9	28,13	6	18,18
	Total	32	100	33	100

4 Conclusions

While investigating potentials of mobile technologies used by university students, we obtained the following results:

1. researches on the issues of mobile technology application in the classroom environment are analyzed;

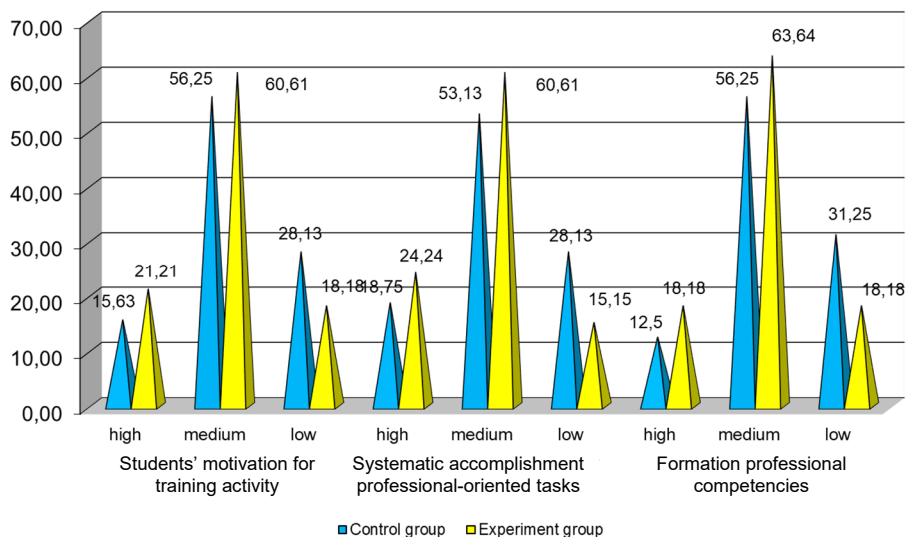


Fig. 17. Generalized results of the experiment

2. methods of applying audience response systems by taking Plickers as an example and mobile tools of multimedia development through using augmented reality tools are developed;
3. functionality of audience response systems and mobile tools of multimedia development with augmented reality are compared and assessed;
4. efficiency of developed methods is experimentally verified and confirmed, namely the results of the “Students’ motivation for training activity” criterion increased by 5,58% at the high level and by 4,36% on average; the results of the “Systematic accomplishment professional-oriented tasks” criterion increased by 5,49% at the high level and by 7,48% on average; the results of the “Formation professional competencies” criterion increased by 5,68% at the high level and by 7,39% on average.

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The Use of Digital Technologies for Flipped Learning Implementation

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Abstract. The article presents the study of the use of digital technologies for flipped learning implementation. In this context, the use of the virtual learning environment has been analyzed. The assessment of the efficiency of flipped learning implementation based on this environment and the process of defining the ways of improving the components of the scientific-methodological system of flipped learning was carried out using the technologies of machine learning. The innovative and personalized nature of flipped learning implemented with the use of the virtual learning environment is a methodological condition for increasing the students' interest in learning, activating their study process, revealing their cognitive and personal potentials as well as developing digital competences, independence and individuality etc. The authors emphasize that the use of flipped learning based on digital technologies requires thorough development of the virtual learning environment, a detailed selection of the study content and its adaptation to the concrete groups of students. By stating this we mean the search for more effective and systemic ways of achieving learning objectives: the methods of problem-based learning, flipped learning; the selection of digital tools for presenting lecture materials, development of supplementary tasks; correction of the theoretical materials and the tasks on the basis of the study results and achievements of the students; motivating students to work with the study materials on their own etc. Machine learning was used to group the students by clustering the results of their educational achievements. Based on these data, the personalized learning vector, characteristic of a specific group of students, was determined.

Keywords: digital technologies, flipped learning, virtual learning environment, machine learning, cluster analysis, innovative pedagogy.

1 Introduction

Nowadays, we cannot imagine the field of education without the use of digital technologies in the education process. With the appearance of virtual learning environments, we may observe a rapid accumulation of educational data. In conditions of

active free use of digital educational environments, the assessment of the data of virtual learning environments with the use of machine learning methods is becoming more and more significant.

In modern conditions, a society requires educational services that follow the principles of student-centric education thus making the student a central figure of the teaching process. In this context, innovative teaching methods include: shifting the role of a teacher to that of a facilitator, application of interactive, project work and research methods, particularly, the methods of problem-based learning, flipped learning, the clicker technology. In the course of implementation of these principles, the most popular mixed learning model, namely, the flipped classroom model, requires particular attention.

The innovative and personalized nature of flipped learning may be provided with the help of virtual learning environment (VLE), which is a methodological condition for raising the students' interest in learning, activating their study process, revealing their cognitive and personal potentials as well as developing digital competences, independence and individuality etc. VLE contains study materials (lectures, tasks, tests, reference materials etc.) and is a useful tool while introducing the flipped learning method in the process of studying a course.

A. Littlejohn explains the ideas of intellectual and personal students' potentials actualization based on the use of digital technologies. This includes the development of individual learning plans by the students, knowledge artefacts and contemplations on the achievements [1]. Such learning model is focused on how students plan, study, learn, create and reflect/assess, its components include: consuming knowledge, creating new knowledge, connecting with people, contributing new knowledge resources [1].

M. Shyshkina, U. Kohut, M. Popel have conducted a comparative analysis of the cloud learning components, which provide access to mathematical software [2]. O. Glazunova, M. Shyshkina presented the conceptual-methodological foundations for the development of a university cloud learning and research medium [3]. On the basis of the presented methodology, the model and the experimental study, the ways of resources and services integration, of increasing the learning efficiency and of providing access to the necessary educational tools are revealed [3].

The systemic nature of students' individual work in the cloud learning medium was studied by O. Kolgatin, L. Kolgatina, N. Ponomareva, and E. Shmeltser, who emphasize the low cognitive interest of the students as one of the problems that may be solved by personalization of tasks and exercises developed; proper time management; facilitation of students' cooperation; actualization of creative aspects of the tasks etc. [4].

Digital technologies of open distance education were studied by V. Kukharenko, T. Oleinik, they define the problems of open distance learning and of mixed learning as well as suggest ways of overcoming them [5].

In the modern conditions of educational services transformation and rapid educational data accumulation, the integrated use of digital technologies, namely, the VLE and machine learning in combination with teaching techniques of flipped

learning are becoming more and more appealing and relevant. But so far this field has not been sufficiently studied by the researchers.

Thus, such scientists as V. Naidu, B. Singh, K. Farei, N. Suqri claim that machine learning may be the revolutionary approach to finding out the needs of the student according to his/her skills in the course of implementation of the student-centric approach based on the flipped classroom model. They also suggest ways of increasing the effectiveness of flipped teaching by decreasing the number of manual tasks of the teachers [6].

In this respect, there is an important study of flipped learning with the application of machine learning methods (Neural Networks, Naïve Bayes, Random Forest, kNN, and Logistic regression) conducted by J. Nouri, M. Saqr, U. Fors. The authors forecasted the activities of students in the flipped classroom by providing and receiving feedback. Flipped learning is presented as a pedagogical condition of effective learning interaction of students, by managing the educational process, which includes forecasting its results, and is also viewed as a systemic opportunity for using digital technologies [7].

An empirical comparison of clustering machine learning methods with the aim of statistical analysis of the data received in the course of a survey on the presence of an Internet-addiction formed as a result of improper Internet use, which was conducted among the students majoring in computer studies, is carried out by O. Klochko and V. Fedorets [8].

The application of machine learning techniques for processing VLE data will allow the educators to conduct the analysis of the students' learning achievements and determine the ways of increasing the efficiency of flipped learning application on the basis the received results.

Unsolved aspects of the problem. Despite the experience and the result of this issue's study by the Ukrainian and foreign researchers and taking into consideration the novelty of using machine learning for VLE data processing in the course of flipped learning application, the issue of developing the techniques for study content selection and its adaptation to concrete groups of pupils has not been fully solved by the researchers. The problems that occur in the course of looking for effective machine learning methods for solving the set tasks in order to improve the study results also remain relevant. The issues outlined above need to be studied further.

The purpose of the research is to describe the aims, content and ways of broadening the flipped learning possibilities with the application of the virtual learning environment and machine learning.

2 Methods of the Research

The study on the introduction of the flipped learning method with the application of VLE was conducted on the example of studying the subject of Geometry, topic "Geometrical Transformations" in the 9th form.

Flipped learning is a form of learning, which allows change the traditional educational process in an innovative and personally-oriented way. Accordingly, the learn-

ing process is formed on the basis of the following system-organizing components: the students' homework is to watch the videos with the study materials of the next lesson; the students cover the theoretical material on their own, and the study time in class is spent on doing practical tasks [9-13] as well as for discussion and actual application of the theoretical knowledge and defining the optimal ways of its application to the real needs. Thus, flipped learning corresponds to the competence paradigm, which is based on the idea of practical application of knowledge.

A flipped lesson is a nourishing medium, which directly provides the formation of general and special competences. This includes the creation of conditions for gaining [9-13]: experience and practice reflection, development of skills of stating the problem and problematization; ability to set goals and defining the ways to achieve them; actualization of the activity-based and practically oriented nature of learning, i.e. involving the students in the implementation of the socially and vitally significant activity – researching, designing, modelling etc. In this respect, the significant points are: orientation of the study process towards development of the student's independence and responsibility for the results of his/her work, organization of effective discursive interaction between the participants of the educational process and of fruitful group work; an obligatory inclusion of developing and creative tasks into the content of a lesson [14]; actualization of critical thinking [4] as well as of personal and intellectual-value potential of a personality.

In order to implement flipped learning an educational website “Geometrical Transformations” (VLE) [15] was developed; it contains a system of various methodological developments that a teacher may use to work with students while studying the topic “Geometrical Transformations”: a topical plan, multi-media presentations, lesson drafts, tests etc.

The flipped learning technique presupposes a combined form of traditional and e-learning, using the VLE tools. Figure 1 presents a structural model of the scientific-methodological system of teaching students the topic “Geometrical Transformations” based on flipped learning with the use of machine learning techniques. According to the personality oriented approach, a student, as the subject of an educational process, occupies the central place in this model. A teacher is another subject of an educational process. The following blocks were singled out as the other interrelated elements of the scientific-methodological system: target, content, methodological, organizational-activity, diagnostic-comparative (with the use of machine learning tools). This model is designed on the basis of the systemic approach, it is an open dynamic system and it interacts with the educational space.

In order to solve the set tasks, the following research methods were used: analysis of the works of the scientists in the field of application of the flipped learning method with the use of digital technologies; synthesis – in order to generalize and conceptualize the Ukrainian and foreign experience, as well as to particularize the conceptual framework, improving the experience of drafting and developing of an educational website of a teacher, formulating the received results; observation, testing students in general secondary educational institutions (GSEI); observation and conducting surveys among master students, school teachers and university professors; statistical methods and machine learning methods, particularly, cluster analy-

sis, in order to process the results of the research; modeling; drafting an educational website of a teacher.

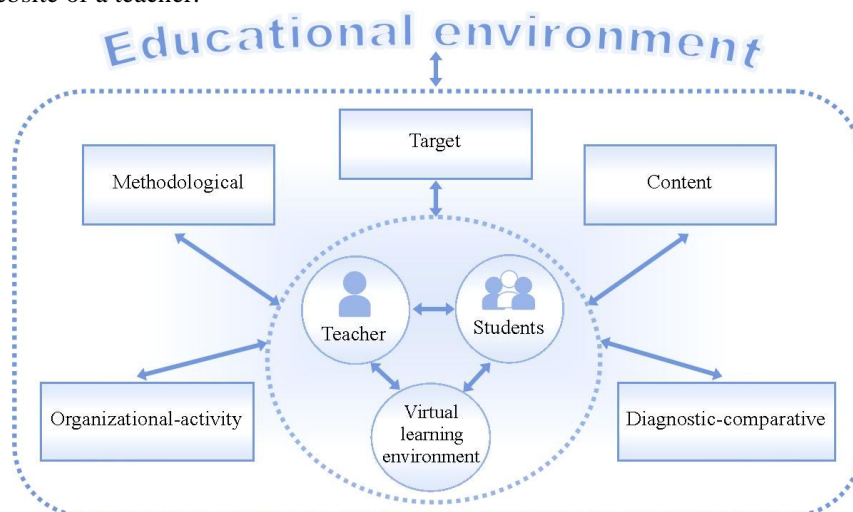


Fig. 1. A structural model of the scientific-methodological system of teaching students the topic “Geometrical Transformations” using the flipped learning method based on VLE with the use of machine learning.

While defining the organizational-pedagogical conditions, needed for successful student training on the topic “Geometrical Transformations” using flipped learning with the application of VLE, we took into consideration: the technical possibilities of a GSEI; the presence of a necessary licensed software; the use of flipped learning in order to form the necessary competences in students; the presence of the necessary methodological materials for giving lessons; forming positive motivation among the students towards studying the topic “Geometrical Transformations” using flipped learning; the use of current digital educational tools and techniques (e.g. the educational websites).

The first stage of the research was ascertaining (April 2019). The purpose of this stage was to study the state of the researched problem and define ways of solving it, carrying out the diagnostics of the initial level of knowledge in Geometry among the students (particularly, in the context of the topic “Geometrical Transformations”). The research was conducted on the basis of the 9th forms of general secondary educational institutions (GSEI) of the Vinnytsia oblast. The number of students involved in the research was 41. Pupils of two classes took part in the experiment, the number of students – 20 and 21 in each class, which we selected as a control and experimental groups respectively.

At the ascertaining stage of the research, the questionnaire method was applied, which allowed us to clarify the organizational conditions of studying the topic “Geometrical Transformations” using flipped learning with the application of VLE in GSEI.

The second stage of the study was exploring (May 2019). At this stage, flipped learning using VLE was applied for studying the topic “Geometrical Transformations”.

This stage included searching for, analyzing and testing the VLE tools and flipped learning techniques with the application of machine learning methods. The students passed the tests several times in order for us to determine the ways of adapting the study content to certain groups of students according to the results of their study achievements. To assess the efficiency of introduction of particular components, a methodology for assessing the study achievements of pupils on the given topic was developed.

The purpose of the forming stage of the research (May 2019) was the assessment of the efficiency of the developed teaching methodology on the topic “Geometrical Transformations” using flipped learning with the application of VLE.

In order to carry out the forming stage of the research, the control and experimental groups of students were taught within the GSEI in accordance with the defined organizational-pedagogical conditions. The control group was taught using the traditional methods and methodology and the experimental group – using flipped learning with the application of VLE.

To compare the results and achievements of the students of the control and experimental groups, we used a Wilcoxon-Mann-Whitney test [16, p. 87]. The theoretical (T) and empirical (W_α) value of this criterion are calculated by the formula (1-2):

$$T=S-n_1(n_1+1)/2 \quad (1)$$

where $S = \sum_{i=1}^{n_1} R(x_i)$ – is the rank sum $R(x_i)$ i-th characteristic x_i ; n_1 – sample size (control group).

$$W_\alpha = \frac{n_1 \cdot n_2}{2} + x_\alpha \cdot \sqrt{\frac{n_1 \cdot n_2 \cdot (n_1 + n_2 + 1)}{12}}, \quad (2)$$

where n_1 is the size of the control group, n_2 – the size of the experimental group, $n=n_1+n_2$; x_α – normal distribution quantile (for the significance level $\alpha=0.05$ $x_\alpha=1.64$).

To detect typical students’ mistakes in order to adapt the components of the scientific-methodological system of teaching students using the flipped learning method based on VLE, we applied such clustering machine learning methods as Canopy, EM (Expectation Maximization) and Farthest First on the basis of the Weka platform [17, 18, 19, 20]. A more detailed description of the EM (Expectation Maximization) and Farthest First algorithms are presented in the work of O. Klochko and V. Fedorets [8, 18, 19].

The main idea of the Canopy algorithm lies in the possibility to decrease the number of distance calculations necessary for clustering by first dividing the data into subsets that overlap according to the greedy algorithm and then only measuring the distances between data point pairs that belong to the subset.

The clustering process using this algorithm can be divided into two stages. At the first stage, we use the shortest distance in order to create a certain number of overlapping subsets, the so-called “canopy”. Canopy is simply a subset of elements (i.e. data points or elements), which according to some level of similarity are located within some threshold distance from the central point. It should be mentioned that some element may be under more than one canopy and that each element must be under at least one canopy [17].

At the second stage, we apply any traditional clustering algorithm using an exact distance criterion, but with a restriction that we do not calculate the distance between the two points that never appear in one “canopy”, considering the distance between them to be infinite [17].

Within the framework of this research, we used the following general parameters for each of the algorithms: the size of the test sample – 215; the number of clusters – 4, determined with the help of validity indices for testing Dunn, DB, SD, CDbw and S_Dbw [21; 22; 23] (Table 1). The test was on Geometry, on the topic “Geometrical Transformations”. They consisted of 10 tasks, for the first 8 tasks you could receive 8 marks (one mark per task) and for the other 2 – maximum 4 marks (2 marks for each task).

Table 1. Number of clusters (calculated with the help of quality indices).

Index	Algorithms		
	Expectation Maximization	Canopy	Farthest First
Dunn	4	6	7
DB	4	5	5
SD	4	4	4
CDbw	4	4	4
S_Dbw	4	5	6

3 Results and Discussion

Having conducted the analysis of the organizational conditions that may be applied in the course of studying the topic “Geometrical Transformations” using flipped learning with the application of VLE, having analyzed the results of the survey conducted among school teachers of the Vinnytsia oblast (15 people), master students majoring in Secondary Education (Computer Studies) and Secondary Education (Mathematics) (7 people), professors of Mykhaylo Kotsiubynskyi Vinnytsia State Pedagogical University (6 people), we have determined the main organizational-pedagogical conditions (see Fig. 2). As can be seen from Figure 2 the following organizational-pedagogical conditions received the highest number of points from the afore stated respondents who took part in the survey: forming positive motivation among the students towards studying the topic “Geometrical Transformations” using flipped learning – 271 points; the use of flipped learning in order to form the necessary competences in students – 261 points; the use of current digital educational tools

and techniques (e.g. the educational websites) – 256 points. The fewer number of points was received by the following organizational-pedagogical conditions (see Fig. 2): the technical possibilities of a GSEI – 169 points; the presence of a necessary licensed software – 137 points; the presence of the necessary methodological materials for giving lessons – 179 points.

Such a result is determined by the fact that if compared with the first three conditions, other organizational-pedagogical conditions, the ones that received a smaller number of points, are not defining, however, they are also important for the respondents. The absence of those organizational-pedagogical conditions that received the highest number of points, makes the integrated use of flipped learning and modern digital tools of educational technologies ineffective. For instance, if students lack the motivation to study the topic “Geometrical Transformations”, it is impossible to achieve high results using flipped learning. As for the need to have licensed software, we may state that nowadays software market offers free software, which can be used in the educational process without a license, namely, Google cloud technologies.

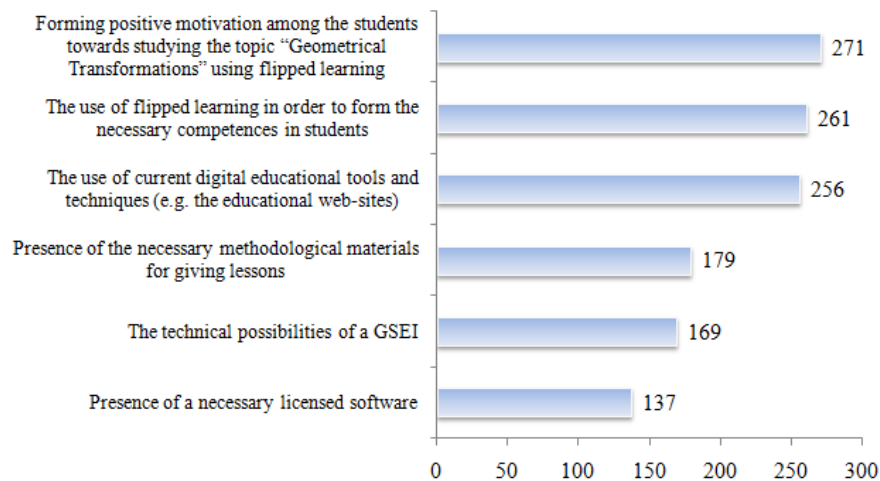


Fig. 2. Results of the respondents’ assessment of the organizational-pedagogical conditions necessary for effective teaching of the topic “Geometrical Transformations” using flipped learning with the application of VLE.

Let us look at the components of the “Geometrical Transformations” website [14], which was used in the course of the study (see Fig. 3): 1) a topical plan highlights the sequence of subtopics, which need to be mastered in the course of studying the stated topic; 2) the “Theoretical Reference Guide” section contains a multi-media presentation on the topic as well as some useful links; 3) the “Lesson Drafts” section contains materials for every subtopic: motivation of the students’ study activity, preparatory tasks for forming the conceptual framework and typical cognitive schemes, tasks for consolidation of the knowledge received, tasks for laboratory work, tasks ensuring the formation of key competences and cross-topic references, test tasks, project tasks;

4) the “Problem Books” contain problem books, training videos and games, which could be used while studying the given topic.

The results of the ascertaining stage of the research have shown that the average level of preparation of students in Geometry at the start of studying the topic “Geometrical Transformations” in the control and experimental groups was relatively homogeneous and was 6.8 and 6.5 points respectively.

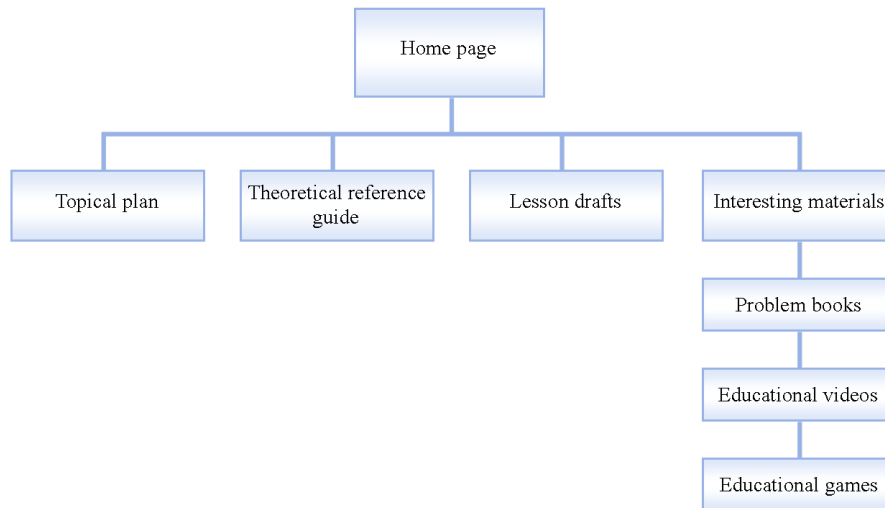


Fig. 3. Structure scheme of the “Geometrical Transformations” website (home page, topical plan, theoretical reference guide, lesson drafts, interesting materials, problem books, educational videos, educational games).

The analysis of the research results showed that after studying the topic “Geometrical Transformations” using flipped learning with the application of VLE, the experimental group demonstrated positive dynamics, but the changes were insignificant (Table 2, Fig. 4). The average point was (Table 2, Fig. 4): in the control group – 6.6, the average level of educational achievements is “sufficient”; in the experimental group – 8.2, the average level of students’ educational achievements is “medium”.

Table 2. Levels of educational achievements of students on the topic “Geometrical Transformations” at the forming stage of the research.

Level of educational achievements of students	Forming stage			
	Experimental group		Control group	
	Number of students	%	Number of students	%
Low, Sufficient	5	23.81	12	60.00
Medium	11	52.38	5	25.00
High	5	23.81	3	15.00
Total:	21	100.00	20	100.00
Average point	-	8.20	-	6.60

Let us prove the statistical validity of the received results. The number of students: control group – $n_1 = 20$; experimental group – $n_2 = 21$.

Using the bilateral Wilcoxon-Mann-Whitney test [16, p. 87], let us check the hypothesis $H_0: P(X \geq Y) = 0.5$, which presupposes that the marks of the students of the control (X) group are with identical probability $P = 0.5$ statistically higher (or equal) to the points of the experimental (Y) groups, i.e. the marks of the students of one group are on average (statistically) higher (or equal) to the marks of the students of the other group. If this hypothesis does not prove to be true, then we accept the alternative hypothesis: $H_1: P(X < Y) \neq 0.5$.

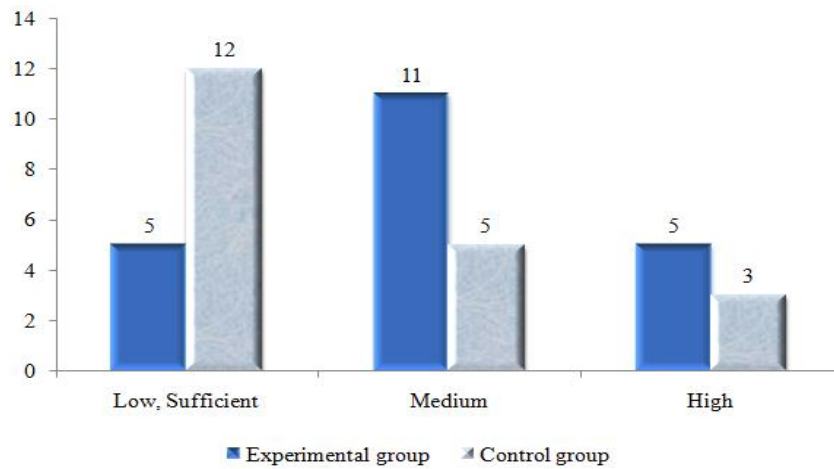


Fig. 4. Levels of educational achievements of students on the topic “Geometrical Transformations” at the forming stage of the research.

On the basis of the received data, we calculate the value of the T criterion by the formula (1):

$$T = 424.5 - 20 \cdot 21 / 2 = 214.5,$$

$$S = \sum_{i=1}^{21} R(x_i) = 24.5.$$

The empirical value of the W_α is calculated using formula (2):

$$W_\alpha = \frac{20 \cdot 21}{2} + 1.64 \cdot \sqrt{\frac{20 \cdot 21 \cdot (20 + 21 + 1)}{12}} = 272.9$$

Thus, $T=214.5 < W_\alpha=272.9$, and according to the decision making rule when using the bilateral criterion, the null hypothesis H_0 deviates at the level $\alpha=0.05$ and an alternative hypothesis H_1 is accepted. We make a conclusion that the level of educational achievements of students in the experimental group is statistically higher than the level of educational achievements of the control group.

In this research, we use clustering methods of machine learning in order to adapt the components of the scientific-methodological system of studying the topic “Geometrical Transformations” using the flipped learning method based on VLE. Namely, determining the main typical mistakes in studying the stated topic that were made in the test taken at the end of studying the topic (students took tests several times). Received the following results:

1. The EM (Expectation Maximization) algorithm (Fig. 5, Table 3). There are 25 objects in the first cluster, 66 in the second, 47 in the third and 77 in the fourth. Objects of the first cluster are the students, whose overall mark for the test approximates 3; objects of the second cluster are the students, whose overall mark for the test approximates 10, objects of the third cluster are the students, whose overall mark for the test approximates 6 and objects of the fourth cluster are the students, whose overall mark for the test approximates 7.

Objects of each of the clusters are united by the fact that most of them have made a mistake in tasks 9 and 10.

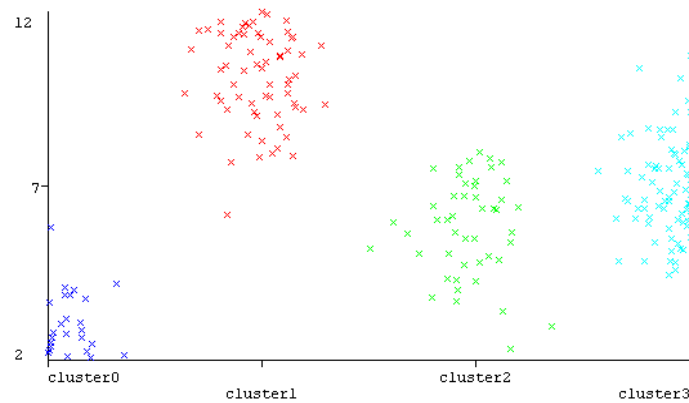


Fig. 5. Visual presentation of the test data after clustering following the EM algorithm.

Table 3. Cluster distribution of the objects, EM algorithm.

Clusters	Clustered Instances
0	25 (12%)
1	66 (31%)
2	47 (22%)
3	77 (36%)

2. The Canopy algorithm (Fig. 6, Table 3). There are 106 objects in the first cluster, 30 in the second, 25 in the third and 54 in the fourth. Objects of the first cluster are the students, whose overall mark for the test approximates 11; objects of the second cluster are the students, whose overall mark for the test approximates 8, objects of the third cluster are the students, whose overall mark for the test approximates 3 and objects of the fourth cluster are the students, whose overall mark for the test approximates 6.

Objects of each of the clusters are united by the fact that most of them made a mistake in task 10.

3. The Farthest First Algorithm (Fig. 7, Table 5). There are 52 objects in the first cluster, 7 in the second, 138 in the third and 18 in the fourth.

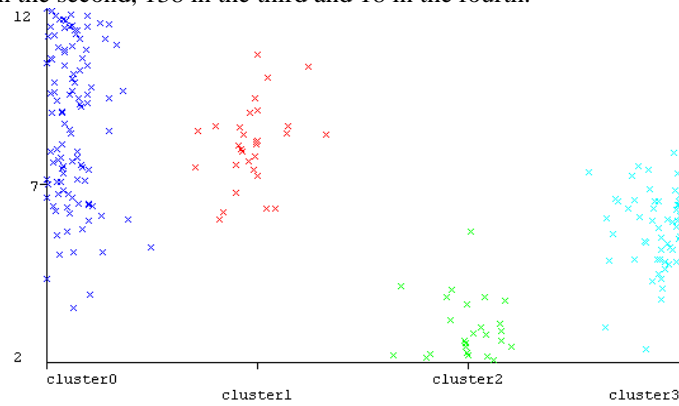


Fig. 6. Visual presentation of the test data after clustering following the Canopy algorithm.

Table 4. Cluster distribution of the objects, Canopy algorithm.

Clusters	Clustered Instances
0	106 (49%)
1	30 (14%)
2	25 (12%)
3	54 (25%)

Objects of the first cluster are the students, whose overall mark for the test approximates 5; objects of the second cluster are the students, whose overall mark for the test approximates 2, objects of the third cluster are the students, whose overall mark for the test approximates 9 and objects of the fourth cluster are the students, whose overall mark for the test approximates 3.

Objects of each of the clusters are united by the fact that most of them made a mistake in tasks 9 and 10.

As a result of using all three clustering algorithms, we may make an overall conclusion that most mistakes were made in tasks 9 and 10 (this refers to both groups):

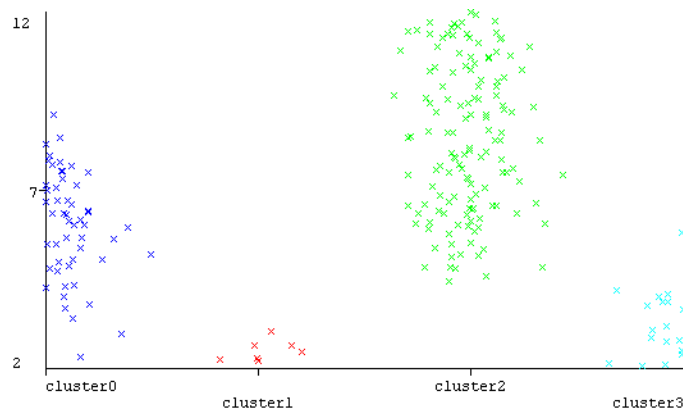


Fig. 7. Visual presentation of the test data after clustering following the Farthest First algorithm

Table 5. Cluster distribution of the objects, Farthest First algorithm.

Clusters	Clustered Instances
0	52 (24%)
1	7 (3%)
2	138 (64%)
3	18 (8%)

Task 9: Find the coordinates of the image of point B (7;-6) under a translation by the vector $\vec{b}(-10; -1)$. Possible answers: 1) (-3; -7); 2) (-3; 7); 3) (17; -5); 4) (17; 5).

Task 10: One rhombus was received from another one by means of rotation. The diagonals of the first rhombus are 12 cm and 16 cm. Find the side of the second rhombus. Possible answers: 1) 14 cm; 2) 5 cm; 3) 10 cm; 4) 20 cm.

Having analyzed the received results, we may conclude that the main reason for these mistakes is the students' incorrect application of the key notions of the topic "Geometrical Transformations" to the geometrical problems of a more general type (this most concerns Task 10).

4 Conclusion

1. On the basis of methodological reflection on the results of the research and analysis of the works of the scientists, we may conclude that using digital technologies for conducting flipped learning is advisable and that the efficiency of the teaching activity increases in conditions of integrated use of the stated learning techniques. Such organization of the educational process is viewed as one of the forms of innovative education as an effective way of implementing the personality-oriented and competence approaches. The advantages of the integrated use of digital technologies and flipped learning include: actualization of the activity-based nature of learning, which includes active participation of students in the process – researching, designing, modelling, perceiving and reflecting on the results and experiences; orientation of the

study process towards the development of initiative, creativity, skills of self-control, reflection and goal-setting as well as independence and responsibility of a pupil for the results of his/her work; stimulating the increase of the students' interest in learning; activating their study process; revealing their cognitive and personal potentials; developing students' digital competences, their independence, individuality etc. Students' motivation for mastering new study material increases considerably as learning parts of the study materials takes place in the course of active creative search outside the classroom, primarily, with the help of innovative tools, using a wide spectrum of digital technologies. At the same time, an important intellectual capacity of teachers and their task is to be able to use and develop their own digital learning tools. The stated organizational-pedagogical conditions allow conducting flipped learning more effectively, in a humanistic and personality-oriented way.

2. In the course of the research, we determined the organizational-pedagogical conditions for implementing the flipped learning method using virtual learning environments. Based on the analysis of the survey results conducted among school teachers, master students, university professors, the following main organizational-pedagogical conditions were defined: forming positive motivation among the students towards studying the topic "Geometrical Transformations" using flipped learning; the use of flipped learning in order to form the necessary competences in students; the use of current digital educational tools and techniques (e.g. the educational websites).

3. The use of flipped learning based on virtual learning environments requires thorough preparation. In order of prepare for such kind of educational process, an educational website "Geometrical Transformations" was created; it is a technological foundation for the introduction of flipped learning at lessons of Geometry while studying the topic "Geometrical Transformations" in the 9th form. The website contains a topical plan, a short theoretical guide, lesson drafts and interesting materials that refer to the topic "Geometrical Transformations" (problems, educational games and videos).

4. The application of flipped learning based on virtual learning environments also requires a detailed selection of the study content as well as its adaptation to concrete groups of students. We assessed the effectiveness of flipped learning implementation on the basis of the stated environment and determined the ways of improving the components of the scientific-methodological system of flipped learning using machine learning techniques. The application of the Canopy, EM (Expectation Maximization) and Farthest First clustering algorithms on the basis of the Weka platform for grouping the results of students' educational achievements in the course of studying the topic "Geometrical Transformations" allowed us to detect the main typical mistakes made by the students. In our case, the main reason for making these mistakes was the students' incorrect application of the key notions of the topic "Geometrical transformations" to geometrical problems of a more general nature. The clustering model presented in the research can also be used for selecting study tasks under the "traditional" organization of the educational process.

5. The analysis of the results of the research using the bilateral Wilcoxon-Mann-Whitney criterion proved the effectiveness of using the stated method at the lessons of Geometry in the 9th form while studying the topic "Geometrical Transformations". It

has been determined that the level of educational achievements of the students from the experimental group is statistically higher than the level of educational achievements of the students from the control group. In addition, after studying the topic “Geometrical Transformations” using flipped learning and virtual learning environments, the experimental group demonstrated positive dynamics of educational achievements; and the control group also demonstrate positive changes, which are relatively insignificant. The average point was 6.6, the average level of educational achievements is “sufficient”; and 8.2 in the experimental group, average level of students’ educational achievements is “medium”; there was an increase of the average level of educational achievements from “sufficient” to “medium”.

The article determines the ways of increasing the effectiveness of flipped learning implementation using virtual learning environments on the basis of machine learning techniques: determining the individual learning trajectory, characteristic of a concrete group of students on the basis of clustering their educational achievements with the help of machine learning; selecting the study content and adapting it to concrete groups of students; searching for more effective and systemic ways of achieving pedagogical goals (selecting and correcting the theoretical materials and tasks, selection of digital tools for presenting the lecture material, development of tasks, motivating students to individually work with the study materials, the methods of problem-based learning, flipped learning etc.). Thus, flipped learning is effective if the teacher takes his/her professional activity creatively and, accordingly, modifies and controls the educational process. It is important to adapt the learning environment to the individual needs of the students and to timely correct the imperfections.

The theoretically and practically significant generalizations, concepts, proposals formulated in the research may be used for improving the quality of education and broadening the possibilities of the educational landscape: in the scientific-research field – for further scientific-practical developments in the stated field; in the course of designing and using virtual learning environments in the educational process.

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Information and Communication Technologies in the Study of Mathematical Methods in Psychology

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Abstract. The article discusses the methodological aspects of ICT in teaching students mathematical methods psychologists. This study examines the problem of the formation of future psychologists in the process of studying the discipline "Mathematical methods in psychology" of professional competence as the ability to independently plan, organize and carry out psychological research in combination with the general competence - the use of information and communication technology. For successful professional activity, future psychologists need to know the principles of finding and selecting methods of mathematical processing of statistical data during psychological research, so a special-purpose software was developed to apply it to solve the applied professional problems of a practical psychologist within the discipline "Mathematical Methods in psychology". The use of information and communication technologies: packages of statistical processing of psychological data MS Excel, SPSS, Statistica, etc. or special-purpose software in practical classes on mathematical methods in psychology –is quite a regular phenomenon in the era of informatization of education, and the effectiveness of their use depends on the quality of teaching methods. The paper presents examples of the application of two methods of psychological research, which are often used by practical psychologists in their professional activity: a technique for the diagnosis of self-esteem of mental states and a technique for the diagnosis of temperament as the basis of psychodynamic features.

Keywords: information and communication technologies; mathematical methods; future psychologists; psychological research, professional competence of the psychologist.

1 Introduction

1.1 Formulation of the problem.

In the context of sharp political and economic changes in our country, there is an urgent need of society for qualified psychologists who can perform a variety of professional duties at a high level. In practice, the psychologist is necessary to conduct experimental studies that take into account the dynamics and trends of the society and the individual. Such psychological research requires the compilation of statistical material and its analysis using modern mathematical methods and information technologies. This situation makes the formulation of educational goals as the use of new information and communication technologies in teaching students of psychology, and as a result, improves their training.

Today one of the most important characteristics of a qualified professional psychologist is the ability to correctly solve professional problems. Exploring the problem of formation of professional competence of future psychologists - the ability to independently plan, organize and carry out psychological research [1], it should be noted that the introduction of information and communication technologies (ICT) in the educational process makes it possible to significantly strengthen the connection of the content of training with the work of a psychologist-practitioner: to provide practical training with significant learning outcomes, significantly reduce human resources utilization, and broaden knowledge of practical needs.

Analysis of curricula and educational programs for a bachelor's degree in specialty 053 - Psychology of Higher Education Institutions (HEI) of Ukraine (V. N. Karazin Kharkiv National University, Ternopil Ivan Puluj National Technical University, Kherison State University, Karpathian University Augustine Voloshin, Borys Grinchenko Kyiv University, Pavlo Tychyna Uman State Pedagogical University) indicates that curriculum developers in These HEIs consider it necessary to introduce a subject such as "Mathematical Methods in Psychology", although in some HEI this subject is identified with mathematical and statistical methods in psychology.

120 to 240 hours are allocated for studying this discipline in different HEI of Ukraine.

According to the educational-professional program "Psychology" of the first level of higher education [2], during the study of the discipline "Mathematical methods in psychology" at Kremenchuk Mykhailo Ostrohradskyi National University, psychology students have:

- formulate the purpose, objectives of the study; have the skills to collect primary material, follow the study procedure;
- Reflect and critically evaluate the reliability of the results of psychological research, formulate reasoned conclusions;
- present the results of your research orally / in writing to professionals and non-professionals.

In doing so, students acquire the application of the following skills of mathematical methods for solving psychological problems:

- the ability to find, process and analyze data from different sources to solve professional problems, including and using ICT;

- the ability to use appropriate software to conduct psycho-diagnostics and experimental psychological studies;
- the ability to analyze and implement in the professional activity of innovation, to make informed decisions;
- the ability to improve and develop their intellectual and cultural level, to acquire new knowledge using modern ICTs and innovations.

The knowledge and skills that are formed in the process of studying the given discipline are used by future psychologists during the conduct of psychological research, namely:

- a first-order ascertaining study aimed at ascertaining the causal connection between the phenomena;
- formative research, which aims not only to study but also to form one phenomenon as a result of the influence of another;
- a second-order ascertainment study, the purpose of which is to compare the effect of one phenomenon on another in groups with different characteristics.

Research these types provides an opportunity for students at all stages of learning to be active and independent in the formation and development of knowledge and skills, which in turn contributes to future psychologists the ability to plan, organize and carry out the psychological study, using modern ICT; to analyze and systematize the obtained results; make informed decisions; formulate reasoned conclusions and recommendations.

1.2 Analysis of recent research and publications.

The problem of the use of ICT in the study of mathematical subjects by students of humanities studied such scientists as O. Adamenko, V. Kirichenko, E. Vakarev, N. Dergunova, R. Ostapenko, and others. For example, E. Vakarev believes that the mathematical competence of the psychologist-practitioner acts not only as a subject but is included in the structure of professional competence. This applies to both the initial diagnostic evaluation of the specialist's data and materials, as well as the reflection, ie the ability to evaluate the effectiveness of psychological measures using mathematical methods of statistical data analysis using modern ICT [3].

The article [4] emphasizes the special importance of the introduction of ICT in the educational process and the interest of scientists in this field of education; on the importance of the acquired skills and abilities, which were acquired as a result of informatization of education and introduction of ICT into the educational process. The types of training directly related to ICT are considered, to which the authors include: distance, e-mail, mobile, blended learning, etc. Such training expands the opportunities and choices for everyone who wants to study or improve their skills or receive additional education.

Also, today published many works on forming professional competence in the preparation of future psychologists while studying at HEI [5] - [12].

Yu. Vintyuk in his papers [6, 7] considered the essence of the problem of training of future professional psychologists in HEI in modern conditions and found that the process of professional training of future psychologists is a means of forming their professional competence.

In the article [9] R. Ostapenko considered a practical lesson he conducted with students-psychologists from the course "Mathematical Methods in Psychology" using reflection. The author determines that the inclusion of students in educational and research activities through reflection - one of the conditions for the formation of the mathematical competence of the future psychologist. R. Ostapenko also concludes the importance of conducting these classes in the context of future professional activity for the wide practical application of modern information technologies and software. In the textbook [10] he considers specific algorithms for processing psychological data both manually and in statistical programs MS Excel and SPSS. This manual selects a large number of examples of the use of mathematical methods in psychology based on real results of psychological research, which are related to the activities of a practical psychologist: correctional, developmental, diagnostic, counseling, prevention, and research.

I. Levinska in [11] analyzed the structure of the professional competence of the future psychologist in foreign psychological and pedagogical studies. Based on leading European and American sources the content of the structure of the professional competence of the future psychologist is revealed.

In her research [12] T. Lavrukina analyzed the information competence of future psychologists and included to her components the following competencies: information-communication, communicative, productive, automation, moral, psychological, subject, social, mathematical and personal qualities of the student. The researcher also determined that the generated information competence ensures that the following psychologists have the following abilities:

- apply ICT not only in the educational process but also in everyday life;
- apply ICT in solving various professional tasks;
- use ICT to explore different information models and more.

The purpose of the article is to substantiate the feasibility of using ICT in the study of the discipline "Mathematical Methods in Psychology" in the formation of the professional competence of a student psychologist.

2 Results

Usually, experimental research in psychology is conducted to test the hypothesis, which is a consequence of theoretical ideas. There are several approaches to organizing an experiment in psychology [13] - [15], but mainly the authors identify four stages of psychological research:

1. Theoretical stage (definition of research topic, formulation of goals and objectives).
2. Preparatory stage (formulation of experimental hypothesis, development of research methodology).

3. Experimental stage (gathering of actual data, testing of experimental hypothesis).
4. Interpretation stage (quantitative processing of research data, graphing, etc., formulation of conclusions).

Most often, the study of mathematical methods in psychology focuses on the last two stages, as the most time consuming and needing knowledge of mathematical statistics. We propose to use such an algorithm of psychological research in practical classes on mathematical methods in psychology.

1. Formulation of the experimental hypothesis.
2. Collection of actual data.
3. Primary data analysis (quantitative processing of research data, graphing, etc.).
4. Choosing a mathematical method of analysis.
5. Testing the experimental hypothesis.
6. Formulation of conclusions.

The processing of statistics data by mathematical methods requires, on the one hand, careful and routine operations, if performed manually, on the other - knowledge, skills, and application of software for statistical analysis of data; in turn, it causes some difficulties because the computer converts some of the numbers that are the original data into the other - the results of processing.

During the practical training in the course "Mathematical Methods in Psychology" without the use of ICT to cover all stages of psychological research - a rather difficult task that takes a long time, and sometimes - it is impossible due to limited time (statistical criteria that include quite complex formulas).

To speed up this process using available software products, such as MS Excel, SPSS, Statistica, and others. But using them again does not make it possible to solve the problem at all stages of psychological research. For example, in MS Excel convenient to just build a histogram, in SPSS - calculate the empirical value criteria.

So, to improve the process of study of the discipline "Mathematical Methods in Psychology", a software tool has been developed [16], which can be used to solve the following problems:

- conducting psychological research to test the effectiveness of the psychocorrection program of negative mental states of the individual;
- conducting psychological research to identify the relationship between temperament and self-esteem of mental states of the individual.

For the first time, the authors combined the work of both a psychologist and a respondent in one software application, which makes it possible to automatically process the statistical data of the experiment and draw conclusions about the mental state of the individual. Performed program calculations allow: to classify the individual by levels of mental states; build visual graphs of temperament distribution in the group; test statistical hypotheses about the effectiveness of psycho-correctional programs.

This software uses tests for the diagnosis of self-esteem of mental states and temperament according to G. Eysenck, which is quite often used by practical psychologists in their professional activity [17].

Let's consider in more detail all the stages of psychological research that can be carried out with the help of the developed program.

The first stage of the algorithm "Formulation of the experimental hypothesis" is positioned as a statement of the problem. For example, the student must develop a program of psychocorrection of the mental states of the individual and check its effectiveness.

To collect data on the mental states of the individual can be used G. Eysenck's test "Self-assessment of mental states", designed to determine the four mental states of personality: anxiety, frustration, aggression, and rigidity. Cystine is an important element in determining the overall adaptive capacity of humans. The test consists of 40 questions, each rated from 0 to 2 points.

So, the second step is "Actual Data Acquisition", which can be done both on paper and with the help of developed software. Fig. 1 gives an example of one of the questions of the first test of Eysenck.



Fig. 1. Example questions during user testing

Next, all the data obtained from the questionnaires should be processed. With the help of the developed tool, you can view the original data after bringing it to a convention for further analysis of the look, which is automatically recorded in the xlsx file (Fig. 2).

The next step is the primary data analysis. The software provides the ability to build conjunction tables and histograms of frequency distributions that are needed to visually compare test results before and after exposure (Fig. 3).

The stage "Choosing a mathematical method of analysis" is not made explicit, but I discuss with students why the Wilcoxon statistical criterion was chosen; what samples we have; on what scale the actual data is measured, and so on.

	A	B	C	D	E	F	G	H	I	J	K	L
1	№	Marks										
2	1	9										
3	2	16										
4	3	13										
5	4	10										
6	5	17										
7	6	9										
8	7	16										
9	8	17										
10	9	20										
11	10	19										
12	11	9										
13	12	9										
14	13	20										
15	14	15										
16	15	17										

Fig. 2. Output in the table.xlsx

.At the penultimate stage of "Testing the experimental hypothesis", after obtaining the test results, the hypothesis about the effectiveness of the impact is tested using the Wilcoxon test. When applying this criterion in the process of manually processing data, for students it is difficult to understand how to rank variables correctly or how to identify typical and atypical shifts in the values of the trait under study. In Fig. 4. in the central table you can see the table of calculations according to Wilcoxon criteria.

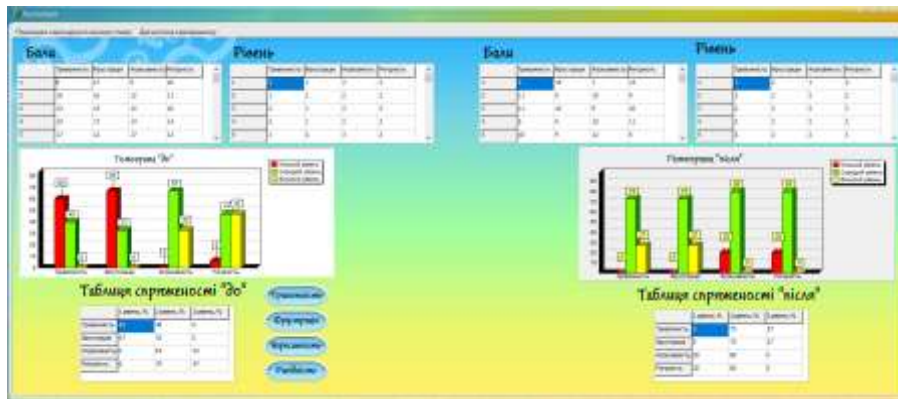


Fig. 3. Program window with primary data analysis after passing the first G. Eysenck test

By applying the above software, future specialists can simultaneously perform real psychological testing, consider the above method, and make the right statistical conclusion at the last stage of "Formulation of conclusions".

The course "Mathematical Methods in Psychology" examines other methods of computation that can be used in solving psychological problems. Therefore, it was decided to add one more test to demonstrate the practical application of the Fisher angle conversion method.



Fig. 4. Program window at the stage of "Testing the experimental hypothesis"

Therefore, the second test is used to diagnose temperament as the basis of psychodynamic features. The two-factor model of personality, proposed by G. Eysenck, allows using the main indicators (extraversion-introversion and neuroticism) to assess the orientation of the individual to the inner or outer world, as well as to reveal the level of emotional anxiety (tension).

Respondents are asked to answer 57 questions. The questions are aimed at identifying the type of temperament of the subject. It is necessary to present typical situations and give the first "natural" answer. Each question must be answered either "yes" or "no".

After obtaining the results of the second test, we hypothesize that there is a relationship between temperament and indicators of self-esteem of mental states using the ϕ^* -Fisher test. This criterion is intended to compare the two samples by the frequency of occurrence of the effect being studied. The criterion evaluates the significance of the differences between the percentages of the two samples that have an interesting effect on the study.

The essence of Fisher's angular transformation is to translate the percentage of particles into the magnitude of the central angle, which is measured in radians. A larger percentage will correspond to a larger angle ϕ^* and a smaller percentage to a smaller angle, but the ratios are nonlinear here. Therefore, mathematical concepts such as inverted trigonometric functions, central angle, radians, and the application of these quantities are quite difficult for non-mathematical students.

Upon completion of the survey, the program provides an opportunity to obtain calculations and conclusions about the relationship between temperament and indicators of the mental state of the individual. Fig. 5 - Fig. 7 shows the windows of the program after passing the first five stages of the second psychological study.

This software tool can also be used by psychology students while writing course work in the course "Mathematical Methods in Psychology" and graduate work of the bachelor.



Fig. 5. Program window at the stage of "Actual data collection"

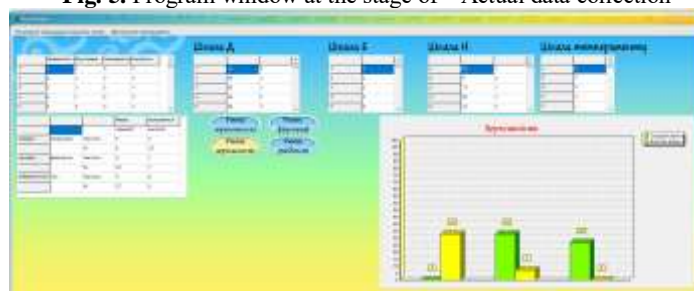


Fig. 6. Program window at the stage of "Primary data analysis"



Fig. 7. Program window at the stage of "Testing the experimental hypothesis"

Let us note the main advantages of using a software tool in solving psychological problems. The training of future psychologists takes place in the course of training in the HEI and should focus on the formation of the professional competence of the psychologist. The software offered allows you to create a system of professional skills that allow you to achieve professional success and self-actualization in practice.

The formation of the professional competence of the psychologist occurs during the implementation of practical classes in the initial discipline of "Mathematical Methods in Psychology", bachelor's course and final works, during practice, and the result of its formation is the development of professional training of the future psychologist, which determines the effectiveness of his practical activity.

3 Conclusions

Therefore, a fundamental role in the formation of future psychologists is fundamental education, in particular, the teaching of mathematics and computer science as a basis for the study of general and specialized disciplines. It is impossible, but important to develop the correct conception of formation and development of thinking, to help to form students' correct ideas about the interrelation of mathematics and professional disciplines, to acquaint future psychologists with some principles of using the methods of activity of practical psychologist and application of ICT.

It should be noted that the use of the developed software in the study of the discipline "Mathematical Methods in Psychology" allows future psychologists to focus on the organization of experimental research in psychology, which contributes to the formation of professional competence - the ability to independently plan, organize and carry out psychological research. When studying mathematical methods in psychology using ICT, future psychologists acquire the following skills: mastering the principles of finding and selecting mathematical methods for analyzing statistics of psychological research; use of basic methods of mathematical processing of results of psychological researches; mastering standard packages of statistical processing of psychological data and special-purpose programs.

The prospects for further research include the experimental verification of the effectiveness of using the developed software during the study of the discipline "Mathematical Methods in Psychology" undergraduate students of specialty 053 - "Psychology" at the Kremenchuk Mykhailo Ostrohradskyi National University.

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Methodology for Teachers' Digital Competence Developing through the Use of the STEAM-oriented Learning Environment

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Abstract. The article focuses on analyzing the experience in using information and communication technologies for professional communication, collaboration and the teachers' digital competence development. The article defines a content, forms, methods and tools as parts of the methodology of using the STEAM-oriented learning environment for the teachers' digital competence development. The teachers' digital competence development is one of the important factors for the establishment and support the STEAM-oriented learning environment in schools. The specialized course "Creation and use of the STEAM-oriented learning environment for the teachers' digital competence development" may contribute to implementing STEAM education in schools. The suggested course on STEAM education for teachers will provide a content, forms, methods and tools as parts of the methodologies of using the STEAM-oriented learning environment for the teachers' digital competence development. Such methodical support of the teachers' training course as instructions and guidance notes on how to use and create e-Learning resources. The specialized course "Creation and use of the STEAM-oriented learning environment for the teachers' digital competence development" is supposed to contribute to the teachers' digital competence development by their acquiring knowledge on implementing STEAM education into the school learning environment.

Keywords: Teachers' Digital Competence Development, STEAM-oriented Learning Environment, STEAM Education.

Introduction

The so-called "Inquiry-based science education" (IBSE) is of particular importance for the information society development. One approach to developing inquiry-based science education is the STEAM-approach, based on a project-based teaching method, focused on the development of skills to solve problems creatively, critically and systematically, by using scientific knowledge within STEAM (Science, Technology, Engineering, Arts, and Mathematics). The main issue is the creation of conditions for the teachers' professional competences development in STEAM education fields, which should influence on the improvement of quality and modernization of education following world trends in science and education. We can state the particular importance

of the teachers' digital competence development and the design of the STEAM-oriented learning environment, which can contribute to continuing teachers' professional competence development. At the same time, it is important to select the necessary Methodology for the teachers' digital competence development.

The article's goal is to define a content, forms, methods and tools as parts of the methodology of using the STEAM-oriented learning environment for the teachers' digital competence development.

Methods of research

To achieve the goal of the study, we used methods of systematic and comparative analysis of pedagogical, philosophical, sociological works, methodological and specialized literature to clarify the problem of creating the STEAM-oriented learning environment, to identify the main ways of using open e-learning resources for STEAM-education support; analysis experience of using the STEAM-oriented learning environment in schools; synthesis and generalization of research literature to clarify the concept of STEAM-oriented learning environment, interpretation of research results within the topic of the article; method of analysis of teachers' questionnaire results.

The Theoretical Backgrounds

1.1 The teachers' digital competence

According to the European Framework for the Digital Competence of Educators (Christine Redecker, 2017) [1], six Digital Competences' areas that focus on different aspects of teachers' professional work: using information and communication technologies (ICTs) for professional communication, collaboration and development; searching, creating and sharing e-learning resources; teaching, managing and organizing the use of ICTs in teaching and learning; assessing the use of ICTs and strategies to improve them; increasing students' opportunities through the use of ICTs, encouraging their learning through research work; promoting students' digital competence, in particular, by enabling students to use ICTs creatively and responsibly, to find information, communicate, create a content and solve problems.

It is important to note, that "educators' digital competence is expressed in their ability to use digital technologies not only to enhance teaching but also for their professional interactions with colleagues, learners, parents and other interested parties, for their individual professional development and the collective good and continuing innovation in the organization and the teaching profession".

The personality's digital competence is the confident, critical and creative use of ICT to achieve goals related to work, employability, learning, leisure, inclusion and participation in society (Anusca Ferrari, 2012) [2].

Taking into account the above mentioned, in our opinion, the digital competence of teachers is their readiness, ability and skills to use information and communication

technologies autonomously and responsibly in their professional activities for solving individual problems and learning throughout their life.

At the same time, it is important to ensure the continued development of teachers' digital competence, which can be supported by ICT and the creation of specialized environments such as, for example, the STEAM-oriented learning environment.

1.2 The STEAM-oriented Learning Environment

The STEAM-oriented learning environment is one of the main trends in the world education, which is defined by the scientists as follows:

- an environment that should provide its users with tools for research in STEM fields involving, where appropriate, the arts, such as music, dance, the visual arts, literature, theatrical arts, humour, or any activity related to the use of art, including visiting museums, listening to lectures, observing various processes, scientific problems or reading scientific literature (Mark E. Rabalais, 2014) [3];
- an environment that should cover such components as object templates according to the learning requests and the students' educational research in STEM fields; software, platforms and other ICTs to provide visualization of educational and scientific materials; training laboratories; study contract – an interactive tool for maintaining a social network that allows students to execute study contracts and connect with other students' communities for logical purposes; training based on the use of blogs by teachers, scholars, students; a system of on-line monitoring and assessment of teachers' professional competencies and students' STEAM competencies (Maïté Debry and Dr. Agueda Gras-Velazquez, 2016) [4];
- an environment that should provide strategies for improving the engineering and technological education of students (Connor, A.M., Karmokar, S. & Whittington, C., 2015 [5]; Dr. Agueda Gras-Velazquez, 2016 [6]);
- an environment that should encompass online teacher communication services with students and colleagues to address learning problems; applications for exchanging information on STEAM training activities and for the ICT participants' hands-on activities; platforms for providing on-line learning and teaching; tools for creating questionnaires and tests; open online libraries and more (Jacina Leong, 2017 [7]; Vimala Judy Kamalodeen, Sandra Figaro-Henry, Nalini Ramsawak-Jodha and Zhanna Dedovets, 2017 [8]); Elaine Perignat & Jennifer Katz-Buonincontro, 2018 [9]).

O. V. Barna, N. R. Balyk (2017) offered the following interpretation of STEAM education: STEAM education provides the study of Science and Technology through the application of technical creativity and Engineering, based on Mathematics, modelling and integrating the use of various tools of other sciences (All) [10]. Analyzing the situation in Ukraine within 2017, the scientists note that the implementation of this approach is very slow, generally in the framework of non-formal learning through meetings with experts, browsing educational scientific channels, sites, developments, participation in competitions, festivals, workshops, picnics, days of science, etc.

1.3 The Results and Discussion

The STEAM-oriented learning environment, in our opinion, should be such an environment that performs the functions of a computer-oriented, mobile-oriented, cloud-oriented, open learning environment through practically-oriented, interdisciplinary and project-based approaches in the study of natural and mathematical cycle disciplines by students; it should develop student’s creative thinking through the use of different branches of the arts in the educational process and promote the development of teachers’ digital competence for students to acquire key competencies and to get them motivated to study these disciplines, to explore various problems in science and be effective in integrating the subjects of primary and secondary education at the national and international levels.

The teachers’ digital competence development is one of the main goals for the creation and using the STEAM-oriented learning environment in schools.

We conducted a survey to study their need to use ICT for the STEAM training in the school curriculum.

We suggested that, by using the service Word Cloud (<https://www.mentimeter.com/>), teachers choose five important tools that can help them develop their creativity and use the STEAM-oriented learning environment in schools (2019). A total of 1542 respondents answered the question “What information and communication technologies are needed to introduce STEAM education into the learning process in schools?” (Fig. 1).



Fig. 1. The map of important tools that can help develop teachers’ creativity and use the STEAM-oriented learning environment in schools according to the answers.

The obtained answers show that 3% of the respondents have chosen Padlet, 1% of them have chosen Kahoot ! and YouTube Scratch; all other tools have been repeated not more than twice, namely: TinyTap, Quizizz, Socrative, Quizlet, Europeana, Tuva Lab, Google Apps for Education, MindMeister, Freemind, Bubble, MindMup, Tinybop, Google Earth, Enercities, BlueBot, Root Coding, Robo Code, Robot Factory by Tinybop, Cyber Robotics Coding Competition, KQED Education, HighAdventure

Science, Education Closet, ArtsEdge, NOVA Labs, GoLab, GeoGebra, PhET Interactive Simulations project, Interactive Physics™ and others.

The same question was also put to the teachers who took part in the webinar “Information and communication technologies for the STEAM-oriented learning environment in schools” (2019). One hundred and twenty-seven respondents reported on which information and communication technologies (tools) they would prefer for the creation and using the STEAM-oriented learning environment in schools. The participants evaluated the proposed ICT by using a five Likert scale ranging from very undesirable (1) to very desirable (5).

Table 1. The survey results regarding teachers’ attitudes to the most relevant ICTs for the STEAM-oriented learning environment in schools.

The most important information and communication technologies as educational resources for creating and supporting the STEAM-oriented learning environment in schools are:	Mean values
Google Drive	4,9
Linolt	2,55
Padlet	4,9
Thinglink	2,7
TinyTap	2,7
Word Cloud	1
Kahoot!	4,5
Quizizz	2,5
GoLab	1,3
Moodle	3,7
Cyber Robotics Coding Competition	0
Surveyanyplace	2,3
Scratch	4,5
KQED Education	1
I don’t know how to use information and communication technologies for the STEAM-oriented learning environment at school	-
Suggest tools	GeoGebra
Total (N= 127)	

Table 1 demonstrates that teachers usually use information and communication technologies for creating and supporting the STEAM-oriented learning environment at school when performing general class activities, as team work and collaborative communication (Google Drive – 4.9; Padlet – 4.9; Moodle – 3.7), also, they use ICTs for assessment (Kahoot! – 4.5; Quizizz – 2.5), but rarely for specific purposes (GoLab – 1.3; Cyber Robotics Coding Competition – 0; KQED Education – 1). It should be noted that five respondents added such tool as GeoGebra.

The mean values in Table 2 indicate what kind of teachers’ skills are important for implementing the STEAM-approach in schools and creating the STEAM-oriented learning environment.

Table 2. The survey results regarding teachers’ attitudes to the most relevant skills for creating and supporting the STEAM-oriented learning environment.

The most important skills for creating and supporting the STEAM-oriented learning environment are acquired through:	Mean values
online tools to create and manage training projects	4,9
online tools for conducting seminar, forums and others	4,9
opening educational resources	4,9
programming languages	2,7
online security tools	3,7
online games	3,5
online tools for creating tests and quizzes	4,5
Total (N= 127)	

Table 2 demonstrates that teachers should develop such skills as using online tools to create and manage training projects; opening educational resources; online tools for conducting the seminar, forums and more; online security tools; online tools for creating tests and quizzes; online games.

The teachers’ answers to the question “What information and communication technologies are needed to introduce STEAM education into the school learning process?” show that it is becoming highly important to use the following ICTs: online tools to create and manage training projects (4,9); opening educational resources (4,9); online tools for conducting seminar, forums and others (4,9); online tools for creating tests and quizzes (4,5); online security tools (3,7); online games (3,5).

According to the results of the questionnaire, we have identified the current problems and issues regarding teachers’ using ICTs to improve the quality of their school STEAM-projects and creation and using the STEAM-oriented learning environment schools. For the first time, we have defined the content, forms, methods and tools as constituents of the methodology for using the STEAM-oriented learning environment for the development of teachers’ digital competence.

The content as a component of the methodology for using the STEAM-oriented learning environment for the teachers’ digital competence development includes the following modules “Creation and use the STEAM-oriented learning environment for the teachers’ digital competence development”:

- Module 1 “The STEAM-oriented learning environment in schools” consisting of the following topics: theoretical principles of creation and use of the STEAM-oriented learning environment in schools; creation and use of strategies for the STEAM-oriented learning environment in schools;
- Module 2 “The use of information and communication technologies to organize and support the STEAM approach in schools” consisting of the following topics: e-Learning resources as the means of teacher's digital competency development to support the STEAM-oriented learning environment in schools; electronic Platform for organizing the STEAM-oriented learning environment in schools;
- Module 3 “Electronic learning resources on self-assessment and evaluation of teachers’ digital competence to support the STEAM-oriented learning environment in schools” comprising such topics as requirements for assessing a teacher's digital

competence for creation and support the STEAM-oriented learning environment; self-assessment of digital competence and its importance for teachers' professional development and support the STEAM-oriented learning environment in schools; planning training activities (lesson plans, learning projects, etc.) to support the STEAM-oriented learning environment in schools. The purpose of the course "Creation and use of the STEAM-oriented learning environment for the teachers' digital competence development" is to develop teachers' digital competence, to create, use and support the STEAM-oriented learning environment.

The main tasks of learning are as follows: organizing practical and theoretical activity of the participants of the educational process, which is conditioned by the regularities and peculiarities of the content for pedagogical activity in the conditions of the STEAM-oriented learning environment in schools; introducing theoretical and organizational basics of the STEAM-oriented learning environment in schools to students; enabling students to acquire the necessary skills to create and use the STEAM-oriented learning environment in schools through the planning and organization of educational activities (lessons, educational projects, weeks on certain sectors for STEAM, etc.) using ICTs; raising the level for teachers' digital competence.

According to The Law of Ukraine on Education (2017) [11] the forms for the organization of the suggested course and training participants may be different: institutional (internal, correspondence, remote, network); individual (external, family, pedagogical patronage, on workplace (on production); dual, that involves the combination of training of persons in educational institutions with on-the-job training at enterprises, institutions and organizations for the acquisition or upgrading of certain qualifications, usually on a contractual basis.

The basic types of classes in the course can be offered in the following ways: workshops, practical seminars, webinars, trainings, computer practical lessons and consultations. At the same time, as for the teaching methods are concerned, we suggest: discussions, exchange of experience, peer-to-peer (equal participation of all participants of the educational process), problematic, story, conversation, explanatory-illustrative, "case-method" (research by participants of the course of different situations concerning the organization of the STEAM-oriented learning environment and determining ways to solve them), demonstration, written survey (questioning), testing, self-assessment, peer-to-peer assessing (mutual evaluation of participants in the educational process of the end products of the course, such as lesson plans, study projects, etc.).

The training process in the course is accompanied by such tools as personal computers, software, e-learning resources that include:

- general educational resources: Flash Cards and Quizzes Apps and Websites (for example, TinyTap, Kahoot!, Quizizz, Socrative, Quizlet, Albert); electronic libraries (for example, Europeana (<https://www.europeana.eu/portal/en>), Ukrainian Center (<http://www.ukrcenter.com>), Tuva Lab (<https://tuvalabs.com/>); Web services for teamwork (for example, Google Apps for Education, Microsoft Office 365 online, Padlet); tools for creating mental maps (for example, MindMeister, Freemind, Bubble, MindMup); search engines (for example, Google, Yahoo!, Baidu);

- resources for specific purposes of the STEAM-oriented learning environment: to review and study various scientific concepts by using models and simulations (for example, Tinybop is for students to work individually or in pairs, to study a particular system as a human body, water cycle, Solar system, etc.; Google Earth VR is designed to explore the Earth and its three-dimensional structures, topography, important historical sites or geographical areas; Enercities is for pupils' modeling of cities, buildings, etc.), programs and websites of Robotics (for example, Blue-Bot, Root Coding, Blockly for Dash & Dot Robots, Robo Code, The Robot Factory by Tinybop, Sphero Edu, Microsoft MakeCode (micro:bit, Circuit Playground Express, Minecraft), Cyber Robotics Coding Competition), online resource centers (for example, KQED Education (<https://ww2.kqed.org/education/stem-resources/>), High-Adventure Science (<https://has.concord.org/>), Education Closet (<https://educationcloset.com>), ArtsEdge (<https://artsedge.kennedy-center.org/educators.aspx>); labs (for example, NOVA Labs, GoLab, GeoGebra); simulators (for example, PhET Interactive Simulations project (<https://phet.colorado.edu/>), Interactive Physics™ (<http://www.design-simulation.com/ip/>), OnlineLabs.in (<http://onlinelabs.in/physics>)). It is important to note that course participants choose e-learning resources, depending on their STEAM-project goals, the form of education chosen for this project (formal, non-formal, informal) and the students' level of education;
- Educational Electronic Platform (E-Platform) for the STEAM-oriented educational environment, which should facilitate the implementation of practical-oriented, interdisciplinary and project approaches in the study of natural-mathematical disciplines and robotics, the formation of students' creative thinking through the use of various arts in the educational process.

One of the requirements for the Educational E-Platform in school is, above all, the selection of software that will meet the needs of teachers to deploy, use and create electronic educational resources, cooperate with all participants in this process and motivate them to teach students.

Among them, Online Learning Platforms users distinguish ten most popular ones in 2019, which are presented on the site "g2.com": Udemy, Infosec Flex, TalentLMS, McGraw-Hill, WebAssign, MyLab, Cloud Guru, LearnWords, WebAssign, Skillshare.

The Educational E-Platform in schools is "specifically known information and telecommunication system work", the goals of which include: technological support for secondary education reform; providing participants with up-to-date educational process, electronic educational resources and services; providing electronic textbooks in open access for students, who completed secondary general education, and competent pedagogical staff; providing and creating the environment for the development of national e-learning resources, services and e-textbooks; development of e-learning and formation of digital competence of participants in the educational process in our country.

The data show that the educational E-Platform for supporting the STEAM-oriented educational environment should host:

- open electronic educational resources, which include resources for students and teachers and can be distributed through e-textbooks, e-libraries, blogs for teachers and teaching staff, Ministry of Education and Science websites, distance courses, etc.;
- tools (ICTs) that provide communication and collaboration between students; between teachers; between students and teachers; between professionals, employers, students, teachers, etc., that can be implemented, for example, throughout open forums, webinars, Internet conferences, etc.;
- online assessment and self-assessment, which can be conducted through contests, competitions, quests, tests, projects, etc., that motivate students to study STEAM and develop teachers' digital competence, to ensure the modernization of education in accordance with demands of the society;
- laboratories covering simulators, games, imitation models, etc.;
- individual profiles of participants of the STEAM-oriented educational environment, where there can be placed the data about participants, their achievements in training, participation in STEAM projects or various forums; certificates, electronic educational resources, necessary for training and teaching.

The course “Creation and use of the STEAM-oriented learning environment for the teachers' digital competence development” is focused on improving teachers' digital competence, which will enable them to create and support the STEAM-oriented learning environment and STEAM-projects for implementing STEAM education in schools.

For example, we offer our project for evaluation of the course by the participants. They should identify the positive aspects of the project and suggest how it can be improved. We have created the Project “Robot and Human”, using Educational E-Platform Graasp (<https://graasp.eu/>) (Fig. 2).

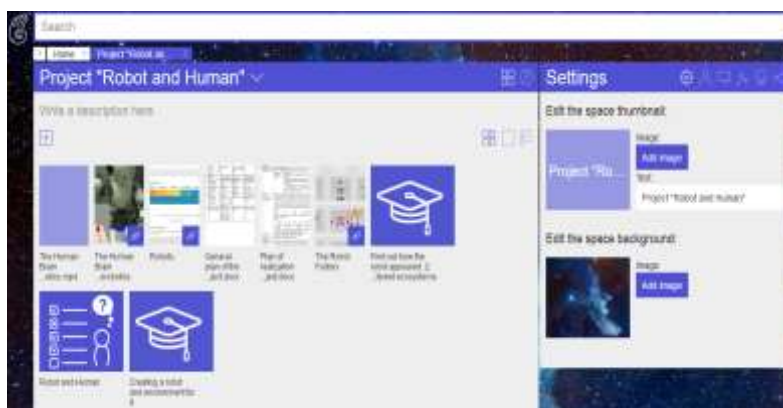


Fig. 2. The Project “Robot and Human” on the Educational E-Platform Graasp

The Project “Robot and human” based on the STEAM approach and designed according to the plan, which is described in the Table 3 “The plan of realization of the educational project “Robot and human”.

Table 3. The plan of the Project “Robot and human” realization.

№	The components of the project	Content	
1	Title	“Robot and human” (the project is designed for students of 5-8 grades)	
2	Basic questions	The key question	Will robots be able to exist without humans?
		Problematic issues	1. How did a robot come about? 2. What are the basic functions of a robot to support various human activities? 3. What should a robot look like in different environments, different ecosystems?
3	Brief description of the project	<p>Robots are gradually coming into our lives. The age of accumulation of knowledge and theoretical science (information society) is moving to a new stage - an era when robots and mechanisms fill the world. According to the latest data, there are now 1.8 million different robots in the world today - industrial, domestic, toy robots and more.</p> <p>Object of study: robotization.</p> <p>Subject Title: Support for human robot functions for different activities.</p> <p>Task:</p> <ol style="list-style-type: none"> 1. Find out how robots appeared. 2. To find out where robots are in human life and what functions they should have. 3. To find out the basic requirements for the support of robots in the conditions of different ecosystems. 	
4	Subjects related to the project	Economics, Language, History, Informatics, Mathematics, Geography and so on.	
5	Assessment of students’ knowledge and skills	<p>Assessment of students’ work in groups is performed according to the criteria created during the discussion over the project effectiveness with students.</p> <p>Self-assessment is done through tests and questionnaires.</p>	
6	E-learning resources	<p>The Human Brain Project SP10- Neurorobotics.mp4 (https://www.youtube.com/watch?time_continue=11&v=rn5PmXQyrjU&feature=emb_logo); The Robot Factory by Tinybop.</p>	

The training courses with such tasks as suggested in “Creation and use the STEAM-oriented learning environment for the teachers’ digital competence development” (organization of practical and theoretical activity of the participants of the educational process, which is conditioned by the regularities and peculiarities of the content for pedagogical activity in the conditions of the STEAM-oriented learning environment in schools; introducing theoretical and organizational basics of the STEAM-oriented learning environment in schools to students; enabling students to acquire the necessary skills to create and use the STEAM-oriented learning environment in schools through the planning and organization of educational activities (lessons, educational projects, weeks on certain sectors for STEAM, etc.) using ICTs; raising the level for teachers’ digital competence) will be highly significant in developing the digital competence of teachers and the introduction of STEAM education in schools.

Conclusions and prospects for further research

The teachers’ digital competence development while implementing STEAM education in schools is one of the important decisions in the process of creation and support of the STEAM-oriented learning environment. Our specialized course “Creation and use of the STEAM-oriented learning environment for the teachers’ digital competence development” may facilitate this process due to providing the course participants with the research materials on implementing STEAM education in schools. The course participants will acquire knowledge of the content, forms, methods and tools as parts of the methodology for using the STEAM-oriented learning environment. This process is impossible without proper methodical support for the teachers’ training course which provide instructions how to use and create e-Learning resources, video lectures, give answers to common questions and the most interesting ones.

The prospects for the further research are to analyze the effectiveness of the methodology of using the STEAM-oriented learning environment for the teachers’ digital competence development, which can be evaluated through the course “Creation and use of the STEAM-oriented learning environment for the teachers’ digital competence development”.

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Blended Learning Method for Improving Students' Media Literacy Level

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Abstract. The paper discusses the issues of improving students' media literacy skills to help them to navigate through an increasingly complex information society. It reports on a project aimed at applying the blended learning model to boost high school students' media literacy levels. The given model is recognized to have a number of advantages for both teachers (tutors) and learners (students). It is generally accepted that the blended learning method provides students with profound theoretical knowledge and retains the emphasis on practice. Besides, online classes offer a great opportunity to reach a wider audience. The purpose of the paper is to describe the authors' experience in introducing a new method for improving the learners' media literacy skills based on the blended learning model. The survey responses demonstrated that the accessibility, ease-of-use, and duration of the classes were deemed effective in terms of students' engagement and increases in their media literacy level. The course helped learners to develop their critical thinking and other media-related skills, to identify propaganda, manipulation, and fake messages found in media streams.

Keywords: Media literacy, Blended learning, Verification, Critical thinking.

1 Introduction

1.1 Research Objectives

The contemporary information-learning environment is characterized by the dominance of new models of learning activity management systems, innovative technologies and solutions, including online resources, diverse cloud services, and other online tools and applications.

Within an education industry framework, the innovative approaches to learning activity management system and information processing are in high demand. Indeed, the given approaches supplement formal teaching methods with greater access to information-learning networks and systems. Besides, they provide information safety and cyber security, as well as encourage the formation of the ICT-competent learner who will efficiently use the power of information resources and tools. In this regard, the

problem of new media literacy formation as the component of a learner's ICT competence comes to the fore.

Moreover, it is important to stress, that modern media and technologies cause numerous challenges concerning different aspects of a person – information society interaction. In the age of information overload, mass media, in particular, social networks reach an extremely massive audience and distribute different types of information. It means individuals have to learn how to orient in the media information field and channels of delivering information to the public, otherwise, they may mistakenly believe fake or manipulative news. Hence, the task of a teacher is to educate his students as autonomous thinkers, able to analyze and critically evaluate the information, to seek the truth, or at least to realize at which direction to move [10].

Today's media provide brand-new and potentially powerful platforms to convey diverse information that fundamentally shape users' lives. Therefore, it is crucial to be able to fact-check and verify the accuracy and truthfulness of the information, to find credible sources of information.

The aim of the paper is to justify the prospects of the blended learning model-based media literacy course to enhance learners' competency level and to specify the perspectives of its introduction into the university curriculum.

1.2 Problem Statement

The analysis of the domestic and international experience of the use of ICT and media tools in the learning process at different educational levels testifies that such class of ICT-based learning tools as media networks constantly attracts the attention of researchers [3], [6], [7], [13]. The tools that are multilingual and diversified and at the same time easy in use, become irreplaceable in maintenance of various processes of learning and research. Online tools constitute the environment for project work and collaborative learning forming innovative pedagogical technologies.

In recent years, there has been an explosion of media literacy educational practices and issues regarding lifelong media literacy development and the teachers' preparedness to introduce media literacy classes into secondary and high school curriculum, to implement media educational innovations, to accept the experience of foreign educators and practitioners, to research media literacy as a component of security competencies, etc. [21]. In this respect, the development of new forms, models and teaching methods that could be disseminated and applied at below secondary, secondary, upper secondary and even tertiary education is undergoing a considerable interest.

In particular, it should be noted that Ukrainian society manifests quite a stable demand for initiating media education programs at schools and higher education institutions and insists on all citizens becoming media literate focusing attention on media literacy in the context of lifelong learning. Furthermore, the introduction of international practices to formulate educational content and create training courses to develop critical thinking skills is still highly relevant.

There is an urgent need to create separate media literacy courses for secondary and high school teachers, students, schoolchildren, to integrate media literacy topics into

existing curricula of secondary schools and departments of higher, higher pedagogical and postgraduate education.

The media literacy courses should be differentiated, depending on the content and purpose of the training and the practical teaching experience. We consider that the best effect can be achieved by introducing separate courses; however, integrated or optional courses, as well as various trainings can also help to achieve the desired result.

What is the purpose of media literacy? Generally speaking, media literacy is defined as the ability to access, analyze, evaluate and communicate messages in a wide variety of forms. More specifically, media literacy is not just about getting some knowledge. The key goal of the teacher is to educate students to evaluate the information provided by media critically, to form a motivational interest in critical attitude, and to teach to create their own media products.

Therefore, there is a necessity to develop media literacy courses for students that should be based on advanced innovations and achievements in this field. Besides, these courses should take into consideration the progressive flexible forms and methods of learning aimed at making the learning process ultimate open, adaptive, focused on the learner's needs, and at the same time easy-to-disseminate in diverse social contexts.

1.3 Research Methods

The study is based on the methods of theoretical analysis, generalization and systematization of scientific facts about the pedagogical processes and phenomena, methods of system analysis and modeling, pedagogical observations and generalization of pedagogical experience, as well as the results of the pedagogical experiment. The study was carried out in the framework of the implementation of the planned research undertaken in the Institute of Information Technologies and Learning Tools of NAES of Ukraine and State University of Telecommunications.

Such interdisciplinary methods and procedures are used in media education studies as analysis and synthesis, induction and deduction, visualization and formalization, expert evaluation, identification and others. It is necessary to acquire them in complex; otherwise, there is not a sufficient level of mastering the material of media education.

2 Research Results

2.1 Previous Studies

The problems of interconnection of social media-based and citizen-led discussions and deliberations supported by e-Participation initiatives, some socio-technical challenges associated with the phenomenon of “duality of e-Participation” have been considered in [14].

The notion of open data has the great impact on the processes of collaboration between citizens and public. The current challenges of the design of an open data collaboration platform, aimed on enhancing transparency, accessing, understanding, and using open data have been analysed in [4]. Usability evaluation of an open data platform in the context of some socio-technical challenges is considered in [11]

The important issue of the studies of social media application is fact-checking and combating fake news and also the search for a methodology for performance analysis of fact-checking organizations [12].

These issues were highlighted in particular within the COMPACT project that was developed in 2017-2020 under the framework Horizon 2020 (<http://compact-media.eu/objectives-social-media-and-convergence/>). The project was devoted to the problems of social media regulation so as to adjust EU regulatory policies. It was aimed at the increasing awareness of the latest technological innovations in the context of social media and content convergence.

In the conditions of rapid development of the e-learning technologies and technological platforms that incorporate the new media it is very important to prepare highly skilled specialists, capable to undertake productive work in information society. Therefore it is necessary to search for new methodological approaches to organization of learning that would assist the deep mastering and understanding of basic concepts, rules, principles and methods of disciplines studies, their relationship to contiguous disciplines, and ways of their use in practice.

The perspective direction is the integration of blended learning courses into the media education learning process.

The most prevalent definition of blended learning currently used in the literature was given by Curtis Bonk and Charles Graham in Handbook of Blended Learning. According to the authors, "blended learning systems combine face-to-face instruction with computer-mediated instruction" [2].

In recent years there has been growing interest in blended learning. Much work on the potential of the method has been carried out by E. Zhelnova, O. Krivonos, V. Kulkharenko, M. Nikitina, A. Stryuk, Y. Trius, G. Cherednichenko, L. Shapran, C. Graham, S. Moebs, S. Weibelzahl, D. Painter, K. Schenk, D. Andrade [19]. Learning analytics within a blended university course based on a socio-constructivist approach was represented by N. Sansone, D. Cesareni [1, 8, 16].

Blended learning on the Moodle has become popular in the system of university education and it is used in Ukraine and Europe. This platform allows using group-work both face-to-face in the classroom as well as online an experience of collaborative knowledge building [9, 15, 17].

Today both Ukrainian and foreign scholars participate in an ongoing discussion about the definition of the concept of blended learning. Conventionally, it is explicated as a combination of traditional formal learning tools (working in the classroom, studying theoretical material) with informal (for instance, discussing debatable issues via email and Internet conferences)(D. Painter). Blended learning refers to a mix of e-learning and classroom training (R. Shank). Moreover, it is interpreted as a combination of distance and traditional communication in integrated learning (S. Moebs & S. Weibelzahl) or as an approach that integrates traditional and computer-mediated learning in a learning environment (S. Graham).

In their groundbreaking paper, G. Siemens et al. demonstrated that blended learning methods are more effective than traditional f2f learning or online teaching without teacher (mentor) guidance [18]

We also take into consideration how some constructivist principles – such as knowledge building, active and self-directed learners, collaborative learning, communities of learners and practice – can be applied to compose the architecture of a blended university course. Principles of constructivism were always followed when setting activities and meetings. The description provided is mainly useful for teachers and educators interested in implementing a blended course with clear references to constructivist pedagogy [8].

Sansone, N., & Cesareni, D. [16] consider the learning analytics within a blended university course based on a socio-constructivist approach. The authors focus on the evaluation system adopted in the course, deliberately inspired by the principles of formative assessment: an ongoing evaluation in the form of feedback shared with the students, and which integrates the teacher's evaluation with self-evaluation and peer-evaluation.

Hence the development of a new area of research in the field of educational sciences, the Learning Analytics (LA) that Siemens [18] defines as the use of data produced by the student and the analysis models to discover information and social connections, and to predict and give advice on learning.

The correct interpretation and placement of the quantitative data, as well as a suitable integration of qualitative and quantitative data, is what is required on the one hand by the teachers, on the other by the learning software and the LA techniques, which must necessarily be developed in close connection with the pedagogical assumptions.[16].

Modern information technologies are gradually becoming an integral part of the education system. The necessity of implementation of digital competency considered at the research of O. Kuzminska, M. Mazorchuk, N. Morze [7]. According to the scientists, nowadays teachers and students in Ukraine have enough skills for organizing e-learning. However, despite they have some differences in their skills, this fact should be taken into consideration while developing a methodology of co-education.

Introducing a blended learning course to personal growth and life skills training is no less important than improving one's professional skills. The ability to navigate in today's overwhelming information flow, analyze and detect fake propaganda and other manipulative messages is a crucial part of the cybersecurity of both the individual and society since the human factor still remains the weakest link in any sophisticated production technique [21]. Therefore, media literacy is a vital aspect of cybersecurity, while the culture of information consumption is a key factor in society's cybersecurity.

We believe that the combination of traditional place-based classroom methods and online learning technologies is a contemporary and convenient method to integrate additional professional and personal development-related courses into the standard education system, in particular for media literacy and cybersecurity learning courses.

We consider this field to be promising to create blended learning courses since it has the potential social impact and will contribute to the rapid expansion of innovations, encompassing as much material as possible, reaching a broader audience and more effective penetration of new technologies into everyday life and education process.

2.2 The Characteristics of the Media Literacy Course Based on the Model of Blended Learning

An obvious advantage of a media literacy course based on a blended learning model is an opportunity to combine online learning with traditional f2f (face-to-face) instruction modes, which provides benefits to both the learner and the course tutor. These courses are partially asynchronous, so the student can schedule online classes on his own. During the in-class sessions, he gets feedback from the teacher, who, for example, can explain difficult concepts or clarify certain issues. In addition, mentoring and classroom planning makes students more disciplined. In turn, the teacher can control the educational process and give feedback. Furthermore, the theoretical material can be available online for participants to enlarge the number of practical classes.

Consequently, we may put forward the *Hypothesis* of the study: The blended learning method will provide students with profound theoretical knowledge in media literacy and retains the emphasis on practical skills. In addition, the accessibility of online classes will offer a great opportunity to reach a wider audience.

The *Purpose* of this introduction will be the next: to improve media literacy level of the students through the use of a blended learning model.

The proposed course will allow students to improve their media literacy level by developing their critical thinking skills and ability to identify cyber propaganda, manipulation, and fake messages found in media streams.

The practical experience of previous media literacy courses conducted by the authors in 2017-2018 [5], [6] and applied place-based classroom methods have shown that teachers need more time to cover the topics fully. Each topic took three to five 90-minutes sessions. We should affirm that time constraints negatively affected the completion of the course with practical material and halved the time required to complete the practical tasks, which included working with information resources. In 2017-2018 the author has conducted the following courses: Psycholinguistic Basics of Media Literacy (five sessions), Online Tools for Photo Verification (five sessions), and Humanitarian Aspects of Cyber security (three sessions).

The Psycholinguistic Basics of Media Literacy training consisted of five sessions. They were targeted at teaching students to analyze text and understand what linguistic manipulation mechanisms were used to influence the audience, why manipulative and fake news tended to spread quickly. Besides, students learnt to create and analyze information contexts.

The Online Tools for Photo Verification training included five sessions where students learnt to verify online photos and pictures by means of free online tools, such as "Tineye", "Fotoforensics" and so on.

The Humanitarian Aspects of Cyber security incorporated three sessions devoted to vishing, phishing and other social engineer tactics. Moreover, it included psycholinguistic methods for analysing fishing letters.

Analyzing the sessions, we found that their duration (thirteen sessions) was the main disadvantage of the course. The number of sessions was incredibly inconvenient for students and caused attendance and group composition problems. Obviously, the given problem cannot be solved by a simple combination of course topics and time reductions

since it will have a negative impact on practical exercises or analysis of important theoretical material.

Therefore, we considered the blended learning method as an effective tool to combine distance learning with in-class sessions. Such a combination made it possible to expand the theoretical material and to add practical tasks for forming (developing) the skills of analysis, evaluation, verification, and differentiation of information. 12 hours (63% of the course time) and 7 hours (37% of the time) were taken by online and in-class sessions, respectively. It will help you evaluate the information flows in your daily life and equip you with skills you can use to recognize disinformation and propaganda (Fig.1).

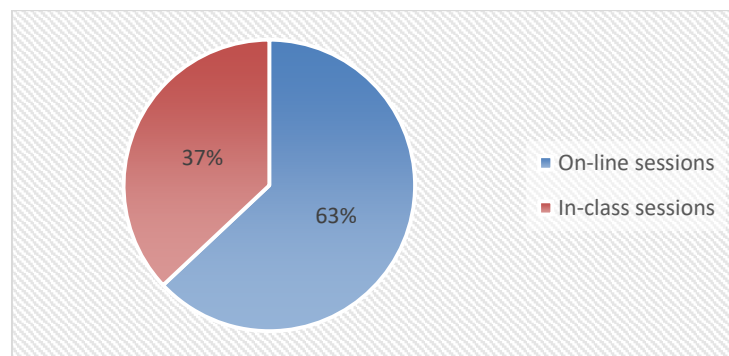


Fig. 1. Distribution of media literacy course time

It is worth noting that this learning method was identified as one of the priorities when applying for the group. When registering for the course, the students filled out a questionnaire, which asked to choose the reasons why they wanted to attend the course. One of the options included "blended learning". 99% of the respondents ticked this item.

Thus, grounded on the data obtained, we can conclude that blended learning is apparently one of the factors to attract students and is an ultra-modern form of learning based on information technologies.

The blended learning method made possible to reduce the number of in-class sessions at the same time providing more theoretical material and paying closer attention to the development of practical skills.

The course included both theoretical and practical classes. Most of the theoretical materials were incorporated into the online classes, while the majority of practical work was done during the in-class sessions. 90-minute classes were held once a week. The course consisted of five in-class (7 hours) and online (12 hours) sessions. The number of training hours was stated in the learners' certificates, issued after passing the final online and in-class tests. Thus, trainees received 7-hour and 12-hour certificates which indicated the course type.

The blended learning course was piloted at the State University of Telecommunications (Kyiv, Ukraine). The training materials were created with the support of IREX, the US educational agency. The online part of the VeryVerified Media Literacy course was hosted on EdEra educational platform. It is a part of the Learn to Discern, the media

and information literacy project, implemented by IREX with the support of the US and UK embassies in Ukraine in partnership with the Ministry of Education and Science of Ukraine [20].

The course was aimed at developing analytical and critical thinking skills, at evaluating the content of modern media. The classes also covered the techniques of influence on the reader's consciousness, which are widely used online.

Each training included five 90-minute sessions. The course was attended by 138 students divided into four groups of 28-30 learners.

Prior to the course, we conducted a survey to determine the rate of students' media literacy.

The questionnaire consisted of three parts targeted at examining a specific aspect of differentiating and analyzing information. When calculating, the statistical error did not exceed $\pm 2.17\%$.

Part One: Reading and Analyzing the Article. This part contained questions to identify the information recognition skills (to single out signs of manipulative content, imposing thoughts and ideas).

The results showed that 66% of respondents could partially recognize truthful information. The greatest difficulty was the question if the judgments in the article were supported by the facts. The percentage of correct answers to all questions was 32%.

Part Two: Discovering Knowledge about Ukrainian Media Sphere. The results demonstrated that 38% of learners did not have sufficient information about the Ukrainian TV-channels owners. The biggest challenge was connected with the owners of INTER, STB, and "Ukraina" TV-channels (20%).

When making clear certain concepts of the Ukrainian media, students found it difficult to explain what filter bubble and hate speech meant (only 10% and 46% of correct answers, respectively).

Part Three: Identifying Information Reviewing and Discerning Skills. Students were asked to answer a set of questions:

A) How to check if a journalist follows professional ethics and standards? Answering the given question, 83% of respondents made mistakes or did not give a complete answer, 10% did not answer the question at all, and only 7% could choose the correct answer from the list.

B) How to check the credibility of experts' comments? Results showed that 78% of learners made a mistake or did not give a complete answer to the question, 14% could not give any correct answer, and only 8% gave correct answers.

C) Then the students were asked to differentiate judgments, thoughts and facts. Students differentiate thoughts and facts with a source and facts without a source. 75% of students made mistakes in determining judgments and facts with a source and facts without a source, 21.5% were able to distinguish between these concepts, 3.5% could not perform the tasks correctly.

As for telling apart hate speech and fake language, 82% of respondents could not recognize hate speech in media texts, 57% were unable to detect fake messages.

The results of the survey showed that students had partial recognition skills, while the main problem was the low level of analysis and recognition skills. Quantitative data

processing demonstrated that the average level of media literacy before implementing the course was 21.3%.

The blended learning method also included topics that expanded the range of ways of discerning online information, for instance, to use logic, psychology, and linguistics (the psycholinguistic component) to analyze texts, and to learn about the humanitarian aspects of cyber security (phishing). Furthermore, the blended learning method increased the time for performing practical tasks to consolidate the newly acquired skills of information verification and differentiation.

The course included basic and additional topics. The main topics were recommended by IREX. Extra topics were provided by the tutor-facilitator to improve students' media and information literacy skills. The additional topics are given after the "+" sign in the list below.

Unit 1 – Media landscape+ psycholinguistic peculiarities of manipulative texts 1.

Unit 2 – Traditional media+psycholinguistic peculiarities of manipulative texts 2.

Unit 3 – Social media+ humanitarian aspects of cybersecurity.

Unit 4 – Misinformation and manipulation+ online tools for photo verification.

Unit 5 – Summary. Project. Students prepare one out of six media literacy-related topics.

Since repetition is a crucial ingredient of student learning, between in-class sessions students repeated and learned new material in the online course.

The online course included videos and online tests on all major topics. The tutor-facilitator checked the material by providing practical tasks and test questions that implied analyzing and verifying information. After discussing and reviewing the material, the students got extra knowledge concerning ways of analyzing and verifying information, which was consolidated by practical exercises (according to additional topics. See topics after the "+" sign).

During the first session, the students learned about six types of content. Besides they got to know what influences the user when perceiving the information, scrutinized the most effective and potential type of contemporary media, and practiced to distinguish actual facts from judgments. Additionally, the students gained an understanding of the psycholinguistic basics of media text analysis and what tools usually used to attract as wide audience as possible.

The second session was aimed at discussing what and who influences the content of traditional media, journalism standards and how journalism standards co-exist with freedom of speech. Moreover, the trainees continued to work on drilling the skills of psycholinguistic text analysis.

The third session focused on social networks, mechanisms of influence on the audience and algorithms that affect the person's account in social networks. Besides, it reported how social engineers could examine one's social network account and exploit the presented information to manipulate and obtain the required data.

During the fourth session, the students learnt how to recognize false information and misinformation, manipulative techniques in the media, to single out hate speech and contract articles (so-called dzhyntsa). What's more, students became competent indistinguishable fake photos with the help of special online tools.

In the fifth session, the students worked on the project and presented their ideas about media literacy.

In the fifth session, students were interviewed to determine their media literacy levels after completing the course.

The results obtained showed that the students significantly improved their theoretical knowledge and practical skills of information analysis and recognition (Fig. 2). Before the course, most students were unfamiliar with certain concepts and fact-checking techniques (the average media literacy level was equal to 21.3%). After the course based on the blended learning model, students' average media literacy level reached 52.4%.

Most listeners were able to analyze the article, its accuracy and truthfulness, to identify signs of hate speech, manipulations and violations of journalistic standards, to separate facts from judgments, to spot phishing, to check photos, and to find out what or who influenced the content of Ukrainian media.

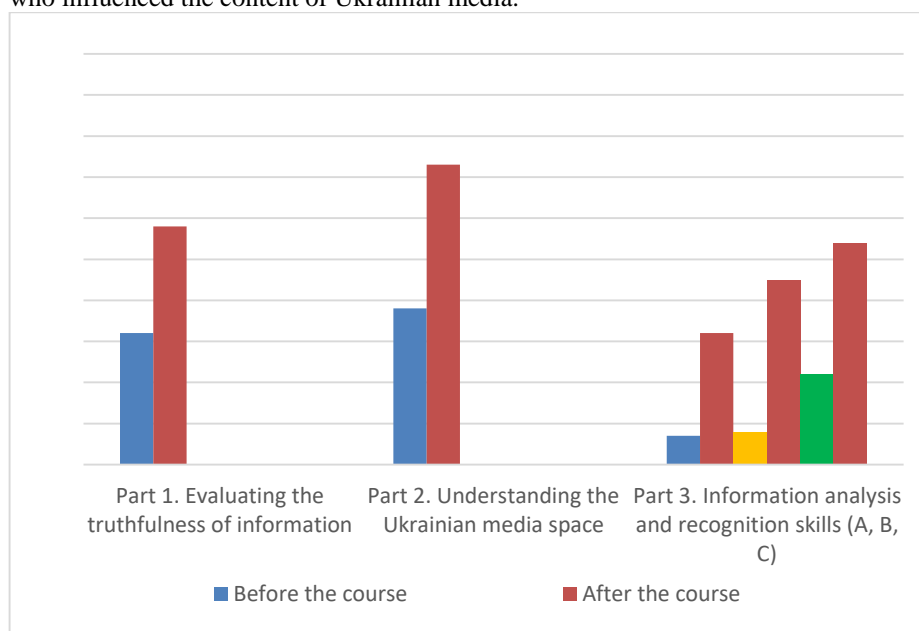


Fig. 2. Comparison of media literacy levels before and after the course

2.3 The Prospects of the Method of Media Literacy Blended Learning Use and Dissemination

The present-day approaches to the development of educational and scientific environment involve the formation of fundamentally new forms of its organization. To meet the demands of contemporary information society it is necessary to modify its composition and structure, the functions of the learning system aimed at intensifying the educational and cognitive activities of its participants.

The purpose of creating an educational and scientific environment of the university lies in satisfying the educational needs of the participants of the educational process.

The above-mentioned needs include gaining access to quality education and more flexible adaptation to the learners' individual features, which can be obtained by providing access to top-ranked educational e-resources and services.

We feel strongly that this problem can be solved by introducing a brand new learning method for developing learners' media literacy. The proposed method is based on the blended learning method and implies the introduction of a number of educational modules that can be used to train scholars, teachers, and students.

The method is aimed at improving the media literacy level of the participants of the educational process, creating the most favorable conditions for personal development, and achieving learning goals. The wide access to new-generation electronic educational resources, information, and analytical tools, improvement of the level of training organization and scientific and pedagogical research, enhancement of teachers and students' ICT competencies will facilitate the process.

In referring to the learning method, we mean "the normative model of the educational process (training) within an educational unit, which indicates the ordering (in terms of time and space, in accordance with the education and upbringing goals and taking into account the selected pedagogical technology) of the student's activities (those, who enrolled in a school or other educational institution) regarding the learning content and the elements of the learning environment of a particular educational unit" [21, p. 310]. Hence, the content of a learning method always alludes to a certain educational unit, comprising educational topics, subjects, and modules.

Since this course is an interactive one aimed at unlimited participation and open access via the web, it allows involving students directly in the learning process. At the same time, the course differs from the classical teaching and traditional classroom-lesson system. The course activities include group work, work in pairs, creative and search-heuristic tasks, content analysis, use of up-to-date technologies for critical analysis of media content, etc.

This training greatly expanded the scope of the classic media literacy course. First, it incorporates advanced modern technologies. Second, students can create digital content both collaborative and personal, which allows them to detect manipulative and fake content.

Moreover, while learning the psycholinguistic basics of text analysis, students take on a variety of roles (consumer, creator, and analyst), acquiring additional knowledge about information recognition.

Thus, learning technical and psycholinguistic aspects along with the media literacy basics are new components in the media literacy training.

Thanks to the online platform, the suggested course has a long-lasting effect and is able to reach a broader audience. Today the online course remains accessible to everyone. It is worth noting the training was attended not only by students, but by teachers, lecturers, and researchers from other universities and scientific institutions. It made possible to extend the course. The online platform contains ready-made learning materials in Ukrainian and English, which can be exploited in group work. Furthermore, after completing the online final test, each trainee receives a certificate that confirms his achievements and states that the learner has enhanced his qualification. We consider it to be an additional incentive to gain media literacy knowledge and skills.

In compliance with the proposed method, the educational content is targeted at forming ICT competencies of scientific and teaching staff, employees of ICT departments, postgraduate and undergraduate students who should know how to use diverse cloud-oriented systems and services in their research and educational process.

The proposed method combines blended learning, verbal (lectures, explanations, discussions), practical (laboratory and practical works, exercises, problem-solving), and online learning methods (distance learning).

Forms of teaching and learning: lectures, practical and laboratory works, group and individual work, optional and training sessions, elucidations and individual consultations.

Means of education: informational educational materials placed on the website of the training course, cloud-oriented electronic educational resources, platforms and services (Google Apps for Education), social network tools and resources (Facebook, etc.), and information resources of the Internet.

Results: widen access to ICT training tools, improved organization of pedagogical researches, enhanced ICT competences of participants of the learning process.

There are two ways to carry out teaching by this method:

- to implement the Media Literacy Technologies in Educational Activities course as a special course for training, retraining, advanced training and further education of scientific and teaching staff;
- to introduce a system of trainings, seminars, webinars, individual consultations, arranged as a pilot experimental study (project) to develop the educational and scientific environment for media literacy courses in an educational establishment.

3 Conclusions and Discussion

The most striking result to emerge is that blended learning was able to improve students' media literacy level after five sessions. It is crucial to note that it significantly exceeded of information materials provided during previous courses based on the traditional F2F learning method. While previous media literacy courses included three to five sessions per each main and supplementary topic, the blended learning-based course allowed incorporating all main topics into five in-class sessions combined with the online ones.

The Quantitative data processing showed that the average media literacy level after the course increased by 31.1%. Thus, blended learning clearly has an advantage over the traditional leaning methods.

The results of this study suggests that blended learning helped:

- to include all the materials of the Media Literacy training in a 5-session course consisted of both in-class and online lessons;
- to increase the number of practical classes;
- to insert the elements of psycholinguistics and information technologies;
- to widen the audience, who could join the course via its online version.

In general, everyone can take the free online course and get a certificate after the successful completion of the online test. The certificate will confirm the learner's achievements. In addition, a media literacy course based on blended learning is seen as part of inclusive education since it allows persons with disabilities to acquire the necessary knowledge and skills to be engaged in the contemporary information society.

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MEASURING THE EFFECTIVENESS OF THE IMPLEMENTATION OF INDIVIDUAL EDUCATIONAL TRAJECTORIES BY UNIVERSITY STUDENTS

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Abstract. Modern information and communication technologies allow to successfully use the methods of effectiveness measurement of various processes in particular in the field of education. From our perspective, success in the implementation of individual educational trajectories by university students requires the assessment model based on the use of modern information technology. In this article, we propose our own methodology for such measuring. It takes into account the entrant's competitive score and student's rating score. The user of the created system can choose the necessary information by criteria such as higher education degree, the form of study, department, and using the graph visualize the implementation of each student's educational trajectory. The presented methodology allows for evaluating objectively the quality of students' individual study plans and can be used in the development of universities rating and ranking criteria.

Keywords: individual educational trajectory, effectiveness measurement, information and communication technologies, university education, verification methods.

Introduction

A substantial reorganization of university education is taking place in Ukraine at the present time. An example of this process is the establishment of the National Agency for Higher Education Quality Assurance in 2015. It is a permanent collegial body empowered to implement state policy in this area. Its powers include the following: development of the standards and criteria of higher education quality assurance, development of the procedure for accreditation of higher education institutions; analysis of the universities activities quality; conducting a licensing examination; preparation of an expert opinion on the possibility of issuing a license to carry out educational activities

in the field of higher education; formation of criteria for quality assessment of higher education institutions activities on which ratings of these institutions be compiled etc [1]. The 2019 Report of the National Agency for Higher Education Quality Assurance emphasized that the problem of quality of higher education in Ukraine remains extremely important not only for integration into the European educational space but also for the cultural and economic development of the nation [2]. In particular, it is important to create a unified methodology for measuring the effectiveness of the implementation of individual educational trajectories by university students. The Law of Ukraine “On Education” (2017) defines this concept as a personal way of realizing the personal potential of an education recipient. It is formed taking into account the abilities, interests, needs, motivation, capabilities and experience of an education recipient and it is based on the choice of the types, forms and pace of education, the subjects of educational activities and the educational programs, educational disciplines and their level of complexity, methods and means of trainings. Individual educational trajectory can be implemented through an individual curriculum plan [3]. We believe that modern information and communication technologies, combined with verification methods, allow creating a valid methodology for measuring the effectiveness of the implementation of individual educational trajectories by university students. The article analyzes these issues.

1 Related work

In recent years, the issue of the quality of higher education in Ukraine has been the subject of a number of papers, in particular in the OECD “Reviews of Integrity in Education: Ukraine 2017” [4] and “Review of the Education Sector” in Ukraine presented by the World Bank [5]. The publication of the Konrad Adenauer Foundation “Higher Education in Ukraine: Agenda for Reforms” [6], prepared by authors from universities and Ukrainian and German academic institutions with the participation of Educational Trends analytical agency analyzes major changes in the field of higher education in Ukraine. The authors paid special attention to the reforms related to the adoption of the Law of Ukraine “On Higher Education” (2014) in the new version. The beginning of implementation in our country of the requirements provided by “The Standards and guidelines for quality assurance in the European Higher Education Area” was acknowledged. It is emphasized that the creation of a modern system of higher education quality assurance is a commitment of Ukraine in accordance with The Ukraine–European Union Association Agreement. The aforementioned 2019 Report of the National Agency for Higher Education Quality Assurance highlights a number of problems in modern higher education in Ukraine. Firstly, the very concept of “quality of higher education” has become relative against the background of a diverse and fleeting market. Secondly, measuring this quality based on certain indicators is problematic and not perfect. Thirdly, the issue of developing objective criteria for rating and ranking of higher educational institutions remains debatable [2].

For example, at Lithuanian Sports University they decided to find criteria of education quality assessment with a help of questionnaire which was given to students. Such quality assurance criteria were investigated: 23 factors that could determine education quality; 33 statement about role of teaching staff and its influence; 35 methods

that could determine material quality on lectures; 14 methods with accessible learning resources for subjects.

In conclusion they found that contents of study, form of curriculum, teaching staff achievements, the level of funding as well as infrastructure, using IT systems and public information were the most important criterias in studying process [12].

Individual monitoring of German universities quality assessment presents individual achievements of each student separately as well as each teacher. Intra-university assessment of education quality includes such criterias as: separate assessment of each student or teacher achievements; teachers monitor the students achievements during the educational process by themselves; administrative assessment is done by the administration of university in the system direction and control [13].

Issued by the Norwegian Agency for Quality Assurance in Education criteria for analysis of quality assurance systems shall involve the entire establishment and shall apply to the square measures of activity that are associated with quality of studies and also the total learning surroundings for all course provisions that the establishment is accountable, each internal and external. In evaluating the standard assurance system, stress is placed on the subsequent aspects of the system.

Active participation by students in work on quality and also the concentrate on the overall learning environment. An annual report on work on quality to the board of the establishment, giving a coherent overall assessment of quality of studies at the establishment and an summary after all plans and measures for work on quality [14].

How the college rankings were calculated in USA.

These square measure the factors and weights utilized in the U.S. News Best schools rankings.

They approach outcomes (35%) from angles of graduation and retention (22%), graduation rate performance (8%) and social quality (5%).

Graduation rate performance: they compared every college's actual six-year graduation rate with what we tend to foretold for its fall 2012 coming into category. the anticipated rates were sculptural from admissions information, proportion of undergraduates awarded Pell Grants, faculty money resources, proportion of federal help recipients World Health Organization square measure 1st generation, and National Universities' maths and science, or STEM, orientations.

Social mobility: Measures however well colleges graduated students World Health Organization received federal Pell Grants (those generally coming back from households whose family incomes square measure but \$50,000 annually, although most Pell Grant cash goes to students with a complete family financial gain below \$20,000).

They conjointly aforementioned however the graduation and retention rate benchmark ranking was calculated. it's all over again computed from a school's total score in these 2 ranking indicators: average six-year graduation rate and average freshman retention rate [15].

Faculty Resources (20%)

Research shows the bigger access students ought to quality instructors, the a lot of engaged they'll be in school and therefore the a lot of they'll learn and sure graduate. U.S. News uses 5 factors from the 2018-2019 year to assess a school's commitment to instruction: category size, college regular payment, college with the very best degree in their fields, student-faculty magnitude relation and proportion of school World Health Organization square measure full time.

Expert Opinion (20%)

Academic name matters as a result of it factors things that can't simply be captured elsewhere. as an example, an establishment well-known for having innovative approaches to teaching could perform particularly well on this indicator, whereas a college troubled to stay its certification can probably perform poorly.

Financial Resources (10%)

Generous per-student defrayment indicates that a university offers a large style of programs and services. U.S. News measures money resources by victimization the typical defrayment per student on instruction, research, student services and connected academic expenditures within the 2017 and 2018 business enterprise years. defrayment on sports, dorms and hospitals doesn't count.

Student Excellence (10%)

A school's educational atmosphere is influenced by the property of its admissions. Simply put, students World Health Organization achieved sturdy grades and take a look at scores throughout high school have the very best likelihood of succeeding at difficult college-level coursework; sanctioning instructors to style categories that have nice rigor.

Alumni Giving (5%)

This is the typical share of living alumni with bachelor's degrees World Health Organization gave to their faculty throughout 2016-2017 and 2017-2018. Giving measures student satisfaction and post-graduate engagement.

2 The System description

The purpose of the development of our methodology is measuring the effectiveness of the implementation of individual educational trajectories by university students using modern information and communication technologies. The starting point of measurement is the indicators with which the applicants are enrolled in a higher education institution [7]. Further, rating scores for the appointment of academic scholarships for students of Kherson State University were taken into account [8]. This information is generally summarized and presented in Table 1:

Table 1. Indicators of measuring the effectiveness of the implementation of individual educational trajectories by university students

Categories of persons / selection criteria	Applicants for Bachelor's Degree	Applicants for Master's Degree	Higher Education Recipient	Alumni
Enrollment based on interview results	+	-	-	-
Competitive (rating) score*	+	+	+	-

*The rating score for the award of academic scholarships to students at KSU is equated with the competitive score by application for the Bachelor's and Master's degrees.

An explanation of some used criteria and concepts in accordance with the "Rules for Entrance to Kherson State University in 2020" [8] is given in Table 2:

Table 2. An explanation of used criteria and concepts

Components of measurement	Contents of the component
Interview	Is the form of the entrance test that involves assessing the preparedness and motivation of the applicant. Based on its results, a protocol decision is made regarding providing an applicant with a recommendation for admission.
Competitive score	Is a comprehensive assessment of the applicant's achievements. The calculation based on the results of entrance tests and other indicators up to 0,001 in accordance with the Entrance Terms and Conditions.
Competitive score for enrollment to the first year for gaining Bachelor's Degree (Master's Degree in the field of medicine) based on the complete general secondary education	<p>Competitive score (CS) = $C1*S1 + C2*S2 + C3*S3 + K4*A + C5*OU$, where C1, C2, C3, C4, C5 are integral weighting coefficients. Their sum for each competition proposal must be equal to 1;</p> <p>S1, S2 - External independent testing (EIT) scores or entrance exams scores of the first and second subjects;</p> <p>S3 - External independent testing (EIT) scores or entrance exams scores of the third subjects and creative competition;</p> <p>A - the average grade of the document on the complete secondary education;</p> <p>OU - a score for the successful completion of the KSU preparatory courses of the specialty, which is given special support.</p> <p>Finally, the competitive score is multiplied by the product of the following factors: AC, IC, RC, PC.</p> <p>The maximum competitive score may not exceed the figures 200.</p>
Competitive score for entrance to Master's degree based on the obtained higher education degree (educational and qualification level).	<p>a) for entrance for the Master's degree in specialty in specialty 081 "Law", in other specialties (except the specialties of branches of knowledge 01 "Education / Pedagogy", specialties 025 "Musical art") according to the formula: Competitive score (CS) = $P1 + P2 + P3$, where the components take into account the specifics of certain specialties;</p> <p>b) in other cases, the competitive score is calculated as the sum of the entrance</p>

	exam scores and the average score of the supplement to the document on preliminary education, taking into account the right to the primary enrollment (by multiplying the competition score by 1.05) to higher medical and pedagogical institutions.
Rating score	<p>Determines a person's place in the ranking for an academic scholarship.</p> <p>Consists of average success score and additional scores.</p> <p>The average success score of student's academic achievements according to the results of semester control is determined on a 100 point scale of assessment. It is 95% of the rating score. Additional scores are 5% (4.75 scores). They are calculated according to the following indicators:</p> <ul style="list-style-type: none"> a) achievements in scientific, scientific and technical activities (2.5% additional scores, maximum - 2,375 scores); b) active participation in international programs, projects, seminars, forums, competitions (1% additional scores, maximum - 0.95 scores); c) active participation in public life (1.5% additional scores, maximum - 1,425 scores). <p>It follows that the maximum student rating score - 104.75 scores (100 scores is the maximum success score + 4.75 is the maximum number of additional scores).</p>

So, we get the initial information from website Vstup.Info. With the help of the parser developed by us, we collect entrants' competitive scores. If a person is enrolled in university, we enter his name and score in the database.

At the same time, we turn the competitive score on a 200-point scale into a 100-point scale in advance. The results of the session a Dean's Office submits in xml file format. The administrator of this platform downloads student success data. According to the results of the semester exams, it is the main information for assessing and rating a student.

As can be seen from the Table 2, the rating score includes the average study score and other scores, including scores for the participation in scientific activities. As the student participates in the scientific activity of the department and faculty, the participation in conferences, publication of articles and abstracts are taken into account. In the articles [9-11], the architecture of the system for scientific activity results evaluating of academic

staff and students based on the following scientometric systems and databases Scopus, WOS, Google Scholar is described.

After passing the exams, the rating examiner checks whether the student has a publications. This can be done through the KSU Publication service. The list of articles written by student K. Panova is given in Table 3.

Table 3. List of articles written by student K. Panova

Title of the article	Scopus	Google Scholar	Web of science	Semantic Scholar
Development of rating systems for scientometric indices of universities	+	+	-	+
Information system of scientific activity indicators of scientific organizations: Development status and prospects	+	+	-	+

This system displays a graph indicating the connections between the authors.

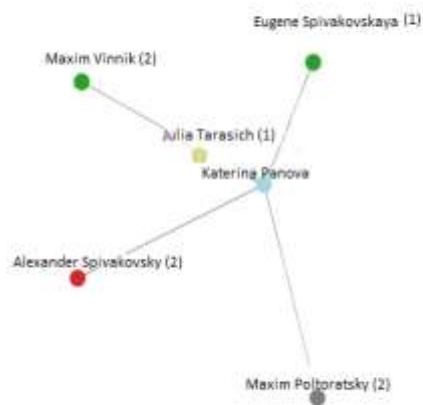


Fig. 1. Connections between co-authors of student K. Panova
The model of data representation in the rating system is presented in Figure 2:

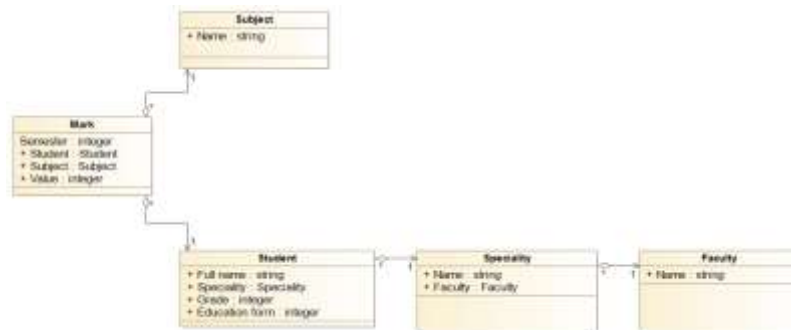


Fig. 2. Model of data representation in the rating system

1. Assessment is the entity, will include such entities as the subject and the student.
2. Student is the entity, will be used as the external key in the entity Assessment.
3. The subject is the entity will be used as the external key in the entity Assessment.
4. Specialty is the entity, will be used as the external key of the Student entity and contains the Faculty entity.
5. Faculty is the entity, will be used as the external key of the Specialty entity. For now, we will analyze the data of only one faculty. In the future, we assume the possibility of the developing of data on several other faculties.

The "administrator" of the system can take such actions:

- Add (delete) the following entities:
 - student,
 - discipline,
 - specialty,
 - rating,
 - faculty.
- Filter by:
 - form of study,
 - higher education degree,
 - specialty.
- Search by:
 - name,
 - specialty,
 - discipline,
 - rating.

It is possible to visualize these requirements with the help of use-case diagrams (Figure 3).

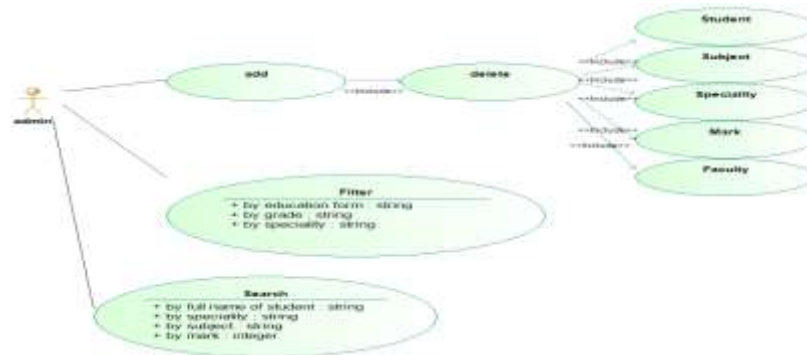


Fig. 3. System Administrator actions

Based on the previous actions we obtain the result presented in Figure 4:

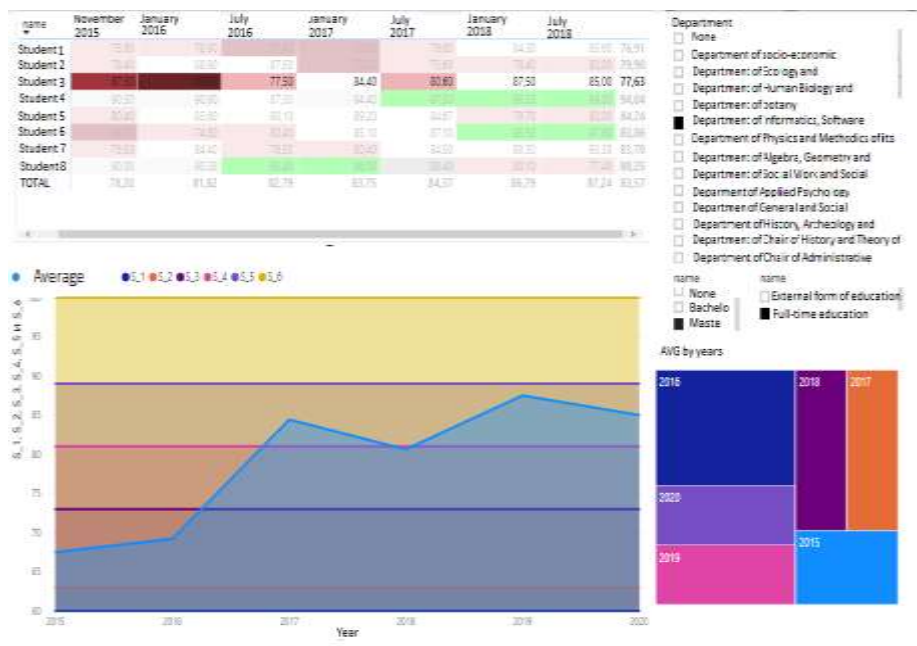


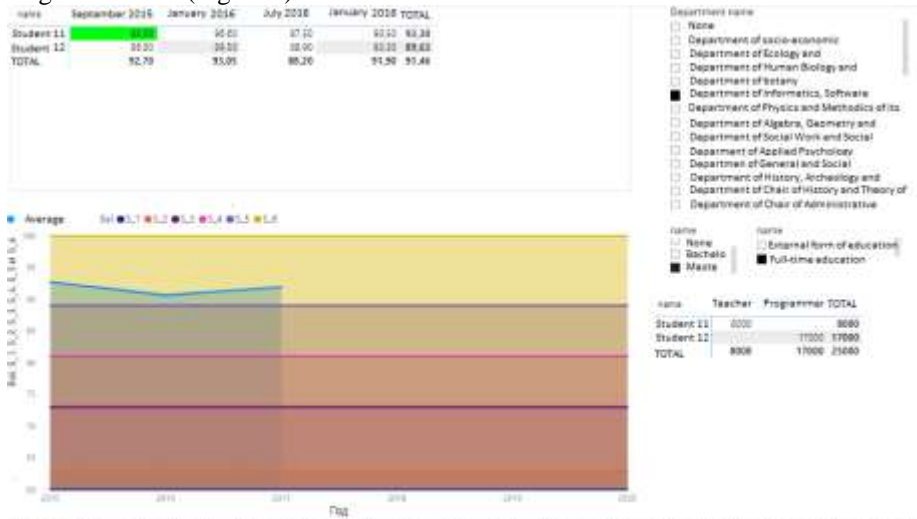
Fig. 4. The basic software of the created system

As can be seen from Figure 5, the system user is able to select the required information by degree, form of study, department, as well as visualize the implementation of the educational trajectory of each student using a graph. Figure 6 shows how filters can determine when a bachelor's student completed the educational trajectory most effectively and vice versa.

name	September 2015	January 2016	July 2016	January 2017	July 2018	January 2019	July 2019	TOTAL
Student 1	90,50	90,90	87,50	94,40	97,50	98,50	99,00	94,04
Student 2	90,00	90,38	95,45	96,00	88,40	80,10	77,40	88,25
Student 3	80,40	85,60	90,10	89,20	84,67	79,70	80,00	84,24
Student 4	66,70	74,60	80,40	85,10	87,10	95,50	97,60	83,86
Student 5	76,50	84,40	76,50	80,40	84,50	90,30	93,30	83,70
Student 6	78,40	88,90	87,50	76,30	75,60	78,40	80,00	79,90
Student 7	87,30	87,30	77,50	84,40	80,60	87,50	85,00	77,63
Student 8	75,60	78,90	87,40	70,20	76,60	84,30	85,60	76,91
TOTAL	78,20	81,82	82,79	83,75	84,37	86,79	87,24	83,57

Fig. 5. Visualization of the implementation of educational trajectories by students

Below is a visualization of the implementation of educational trajectories by Master's Degree students (Figure 6):



Conclusions

It was concluded that the proposed model allows measuring the efficiency of the implementation of individual educational trajectories by university students based on higher education degree, a form of study and the department. The presented method also allows objective evaluating the quality of individual curricula plan of students and can be used in developing criteria for ranking and rating of universities.

It is suggested that based on the trajectories of student success, using the methods and tools of machine learning (ML), the demonstration of malicious behavior of participants in the educational process can be tracked.

By malicious behavior we mean illegal behavior of a student and / or scientific and pedagogical staff, which is manifested in the following violations of academic integrity as defined by Article 42 of the Law of Ukraine "On Education":

- corrupt practices is the provision (reception) by a participant of the educational process or a proposal to provide (receive) funds, property, services, benefits or any other benefits of a material or intangible nature in order to obtain an undue advantage in the educational process;
- biased assessment - deliberate overestimation or underestimation of the assessment of learning outcomes of students;
- providing assistance to students during their assessment of learning outcomes or creating obstacles that are not provided by the conditions and / or procedures for such assessment.

The following trajectories can be considered as patterns of criminal behavior that are indicators:

1. The student(s) has a volatile curve, the average score constantly fluctuates from low to high and from high to low.
2. The student(s) throughout the period of study has / have a low average score, and at the certification receive a high.

These patterns may indicate bribery, biased assessment, and the provision of learning outcomes to learners during their assessment that are not covered by the conditions and / or procedures for such assessment.

These patterns may indicate corrupt practices, biased assessment, and the provision of learning outcomes to learners during their assessment that are not covered by the conditions and / or procedures for such assessment.

3. The student has a high average score throughout the study and at the certification receives a low score.

This result may indicate a violation of the student's right to a fair and objective assessment of learning outcomes due to the biased attitude of the researcher to the student.

Using the proposed approach, the algorithm can be trained in the first three cases and trace other malicious behavior, which is a combination of the three options described above. We also emphasize that the grounds for raising the issue of establishing the facts of academic dishonesty of participants in the educational process, in our opinion, can only be systemic cases, individual ones should be considered as an error.

Prospects for further research are to develop a model for measuring the effectiveness of the implementation of individual educational trajectories by university students which will include success indicators of graduate student, such as employment, salary etc.

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Experience in the Use of Mobile Technologies as a Physics Learning Method

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Abstract. Swift changes in society, related to sciences technicians' development, technologies, by the increase of general volume of information, pull out new requirements for maintenance, structure, and quality of education. It requires teachers to diversify a tool in the direction of the increase in possibilities of the use of mobile technologies and computer systems. Lately in the world, more attention spared to the use of mobile learning, which in obedience to «Recommendations of UNESCO on the questions of a policy in the area of mobile learning» foresees the use of mobile technology, both separate and together with other by informational computer technologies. [1]. Mobile learning allows using the open informational systems, global educational networks, unique digital resources which belong to different educational establishments and co-operate with each other. The use of existent educational resources and creation of own, based on the academic resources from informative space, allows to promote the interest of students to the study of physics, to take into account the individual features, and also features of region and framework of society of the country.

During the last years in Ukraine competency-based approach to the organization of studies certainly one of basic. The new Education Act addresses the key competencies that every modern person needs for a successful life, including mathematical competence; competence in natural sciences, engineering, and technology; innovation; information and communication competence [2]. This further emphasizes the importance of providing students with quality physical education and the problems associated with it. Using mobile technology in professional teaching work, the teacher has the opportunity to implement the basic principles of the competence approach in teaching physics. An analysis of the data provided in the official reports of the Ukrainian Center for Educational Quality Assessment showed that the number of students making an external independent assessment in physics and choosing a future profession related to physics has decreased significantly. This is due to the loss of students' interest in physics and the complexity of the content of the subject, as well as the increase in the amount of information that students need to absorb. In this article, we explore the possibilities of mobile technology as a means of teaching physics students and give our own experience of using mobile technology in the process of teaching physics (for example, the optics section in primary school).

Keywords: mobile learning, mobile applications, mobile technologies, informational computer technologies (ICT), physics, learning method, curriculum.

1 Introduction

Worldwide, education is a major global priority, a major driving force behind the empowerment of people [3].

Education is the basis of personal development, its successful socialization, economic well-being, the key to the development of society and the country [2]. Therefore, in Ukraine, as in the world, great attention is paid today to expand access to quality, competitive education, following the needs of society, individual characteristics, abilities, and needs of education recipients, the possibility of continuing education throughout life [4].

Understanding that the use of mobile technologies enhances access to quality education, especially in subjects of technical and natural sciences, leads to the fact that their use is gaining popularity around the world. According to UNESCO, mobile technologies can significantly expand learning opportunities in any environment. Indeed, today, mobile devices (mobile phones, tablets) are used everywhere by students and teachers to obtain information, organize, refine different forms and stages of the learning process, manage the learning process, and use innovative methods. [1].

The use of mobile technologies in the context of quarantine in most countries in connection with the threat of COVID-19 coronavirus is of particular relevance, which makes it necessary to organize distance learning of educational recipients at all educational levels. The article aims to present the experience in implementation of mobile technologies (in particular, mobile applications, platforms, and resources) as a means of teaching physics students (based on the analysis of mobile applications, platforms, and resources, educational and methodological support for the education of optics students in primary school was developed).

2 Related Works

The analysis of the literature and Internet resources allowed us to find that:

1) mobile technologies - learning technologies based on the use of mobile devices, mobile applications and services, as well as mobile communications in the learning process [5], today is one of the areas of information technology (ICT), rapidly developing and can be used both individually and in combination with other pedagogical technologies to achieve a common educational goal;

2) mobile technology - as a learning tool, includes a wide variety of digital and portable mobile devices (smartphones, tablets, etc.) and related software (mobile applications and services) that enable operations to receive, process and disseminate information [6];

3) Many aspects of the use of mobile technologies have been devoted via work of many native and foreign scientists, in particular:

- The psychological features of the use of mobile technologies are devoted to the work of such scientists as P. Kirschner & J. Jeroen van Merriënboer [7];

- the current state and possibilities of using mobile learning and mobile educational environment – J. Traxler [8], V. Bykov [9], M. Ky'slova, S. Semerikov, K. Slovak [10], Y. Trius, V. Franchuk, N. Franchuk [11];

- the use of mobile technology as a means of teaching physics – T. Compernelle [12], O. Lyashenko, S. Tereshchuk [13];

- mobile, information technology and learning tools from a systemic approach – M. Stryuk, S. Semerikov, A. Stryuk [14];

- use of various mobile applications and services in the educational process – S. Carretero, R. Vuorikari, Y. Punie [15], J. Krause, K. O'Neil & B. Dauenhauer. Plickers [16], I. Korobova, T. Goncharenko, N. Golovko, O. Hniedkova [17], however, the methodological development of lessons using mobile technologies is insufficiently covered;

4) UNESCO identifies the unique benefits of mobile learning, including empowerment and equal access to education; personalization of training; instant feedback and evaluation of learning outcomes; learning anytime, anywhere; effective use of class time; formation of new student communities; support for situational training; development of continuous "seamless" training; providing a link between formal and non-formal learning; minimization of the consequences of the destruction of the educational process in military zones; conflicts or natural disasters; assistance to students with disabilities; improving the quality of communication and management; maximizing cost-effectiveness [1];

5) mobile learning is considered [9, 10, 14] as a separate area in the use of ICT in education, with scientists identifying several advantages of using mobile technology over traditional ICT, in particular: accessibility of mobile devices and mobile applications and services; the opportunity to study anywhere, anytime; compactness of mobile devices; development of related technologies related to the transmission and storage of information on the Internet (cloud technologies); continuity of access to training materials; increased interactive learning; ease of use; personalized learning [11, 18, 19];

6) at the same time, the question of the use of mobile phones in the educational process is debatable today. In many countries, restrictions are imposed on their use at school: 1) in 2018, France adopted a law prohibiting the use of mobile phones in primary and secondary schools [20]; 2) in some schools in the US and Europe use the so-called a Yondr Pouch, a small bag with a magnetic lock that holds a cellphone in the class [21]; 3) in Victoria (Australia), as of 1 semester 2020, mobile phones in all public schools must be excluded and stored throughout the day, except for educational purposes [22]; 4) The UK has announced in 2019 its intention to ban mobile phones in schools, with exceptions to the ban when students use phones to monitor their health or to provide a lesson to students using mobile phones. [23]. Thus, in most countries, there are some restrictions on the use of mobile phones by

schoolchildren, but educational institutions are allowed to use mobile technologies for educational purposes within the framework of M-learning;

7) The main uses of mobile technology in the educational process are the use of mobile applications, platforms, resources, and mobile sensors. The subject of the study of this work has been selected for mobile applications.

Highly appreciating the research and the achievements of scientists on this problem, it is necessary to point out the need to continue scientific research in this area, in particular the study of the possibilities of using mobile technologies as a means of training students of physics and the development of appropriate educational and methodological support.

The analysis of existing mobile applications, platforms and resources has led to the conclusion: there are a large number of applications freely available (Google Forms, Survey Monkey, Kahoot!, Socrative, Plickers and many more), they can work in different operating systems (Windows, Linux, Android) and can be used by both students and teachers during lessons as well as self-study at home. Features of using different mobile applications and services are listed in Table 1.

Table 1. Features of use of various mobile applications and services

№	Name of mobile app, service, and more	Content and activity orientation	Time to use in the learning process
1	Google Forms	allows you to create large-scale surveys with questions of different types; provide students with answers from their own mobile devices	while working in the classroom, and remotely (polls for a long time)
2	Google Classroom	allows you to create, distribute and classify tasks; track the progress of each student, adjust feedback by commenting on student performance	while working in the classroom, and remotely (use for a long time)
3	Kahoot!	rapid processing of test or survey results	when working with a classroom audience
4	Socrative		
5	Plickers		
6	web browser Chromium	storing and using information regardless of the equipment used to access cloud resources; Allows cloud technology	independent choice of tasks and time for their execution; lets you work on your mobile phone

7	cloud environment Dropbox	to synchronize the work of received data across devices	(smartphone) from where it was suspended on your computer and vice versa
8	Moodle	information environment for distance education	while working in the classroom, and remotely
9	Get a class: Smart	includes materials in physics: videos, theoretical materials, physical problems, virtual labs, virtual experiments, preparation for final exams	while working in the classroom, and remotely, independently
10	Physics virtual lab		
11	Science experiments in physics lab		
12	Physics at school		

These resources offer a wide range of educational services from studying theoretical material, watching video lectures, performing practical tasks (solving problems, performing a virtual experiment, etc.) to creating and passing tests and various control tasks aimed at helping students and teachers in physics training. When using these applications, the teacher can perform supervising, teaching, orienting, educational functions. These additions help to increase the cognitive interest of students and the quality of their teaching, and also allow the teacher to organize the preparation of students in physics and evaluation of their activities: 1) the level of knowledge of theoretical knowledge that can be revealed during oral or written questioning, testing; 2) the level of ability to use theoretical material in solving physics problems of different types; 3) level of practical skills that can be found during laboratory work and physics workshop; 4) content and quality of students' creative work.

3 The Presentation of Main Results

There are: plot, informational and methodical parts in the structure of training case. The analysis of the considerable amount of resources that can be used in mobile technologies has led to the need for questioning of physics teachers and students to study their experience of using mobile technologies. The results of the questionnaire made it possible to identify a list of mobile tools and applications that could be used in physics lessons by teachers and students without additional training in their use, or by providing methodological recommendations. Pupils of 9-10 grades of general secondary education institutions, totaling 82 persons, were involved in the questioning. In Fig. 1 shows the distribution of students by choice of applications that they use most often on their mobile devices: 1 - browser (Google, Opera, etc.) - 85%; 2 - "mail client" - 77%; 3 - «instant messaging client» (Viber, Telegram, WhatsApp) - 85%; 4 - applications for communication on social networks (Instagram, Facebook,

Twitter, etc.) - 78%; 5 - educational applications (Castle Quiz, Duolingo, MalMath) - 20%; 6 - e-book reader applications (CoolReader, FBReader, Play Books) - 15%; 7 - office applications (Word, Excel, etc.) - 10%; 8 - dictionaries and translators - 44%; 9 - mobile games - 92%.

The results of the survey indicated that students most often use mobile devices for gaming applications; various browsers, instant messaging clients, social media applications; the least students use e-books, training applications, and office applications (Fig.1).

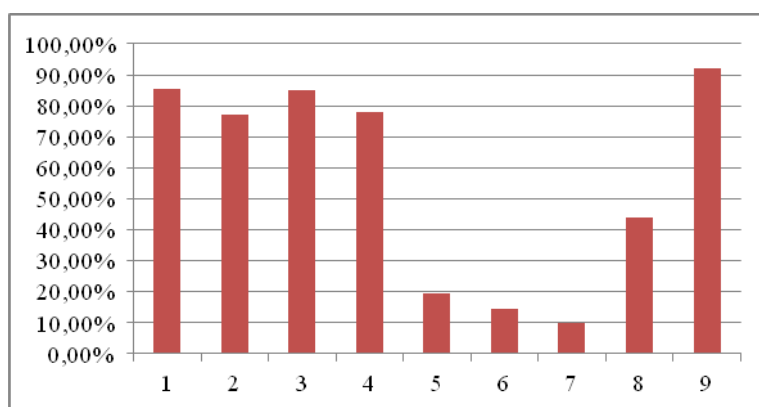


Fig.1. Categorization of students by mobile app usage level

When asked about the convenience of ways of perceiving new material, the students' answers were distributed as follows: 10% prefer reading the text of the textbook; 16% better perceive information through pictures and diagrams in the textbook; 22% - use audio and video snippets to improve the perception of new educational material; 52% expressed a desire to learn new material in the form of a game.

To the last question of the questionnaire regarding the modernization of the process of studying physics through the use of mobile applications, 94% of the observed respondents gave a positive answer.

Summarizing the results of the questionnaire survey of students, it can be argued that students are actively using mobile tools and applications in everyday life, but not for the learning process.

A survey was also conducted among physics teachers in Kherson (17 people).

The survey results indicated that only 23% of the teachers could define the concept of "mobile technology"; 71% know and use mobile technologies, but cannot give a clear definition; 6% did not encounter mobile technologies (Fig.2).

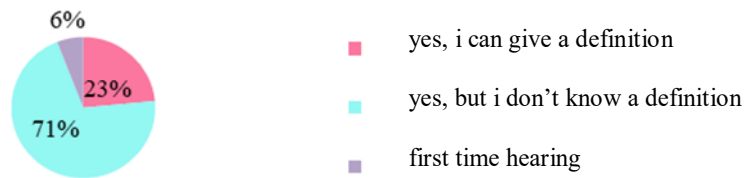


Fig.2. Distribution of teachers' answers to question 1

The second questionnaire revealed the level of awareness of teachers with mobile applications adapted to the study of physics in Ukrainian schools and their use in the educational process. 12% of teachers surveyed know and use mobile applications in their professional activities; 41% of respondents know, but do not use mobile applications in the educational process; 47% do not know about mobile applications (Fig. 3).



Fig.3. Distribution of teachers' answers to question 2

When asked about the possibility of using a ready-made mobile application in their professional activity, 76% of the interviewed teachers expressed a desire to introduce innovations in the educational process, 18% - hesitated about the introduction of mobile technologies, and 6% did not see this need (Fig. 4).



Fig.4. Distribution of teacher responses to question 3

To the question of whether the use of mobile technologies in the process of teaching physics in the development of students' interest in the study of physics and enhancing their educational achievement, 94% of teachers gave a positive answer (Fig. 5).

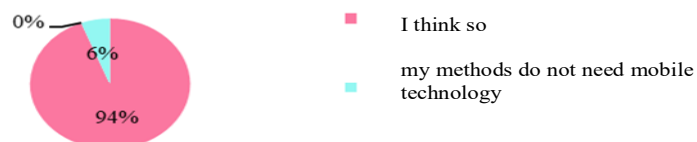


Fig.5. Distribution of teacher responses to question 4

Summarizing the results of the survey of teachers, we can say that they are ready to introduce innovative teaching methods in the educational process, in particular the use of mobile technologies in teaching physics. The results obtained once again confirmed the relevance of the chosen research topic and prompted the development of methodological recommendations for the use of mobile technologies in physics lessons in primary school. The analysis of mobile applications and literary sources on the application of mobile technologies in Physics learning allowed developing planning for the use of mobile technologies as a means of teaching physics students in studying the phenomena of light in grade 9 (Table 2). At the same time, among the many analyzed mobile applications, programs, games, and sites, we have chosen to use five of them to study light phenomena: Get a class: Smart; Physics virtual lab; Science experiments in physics lab; Physics at school; Plickers (Table 2).

Table 2. Planning the use of mobile technologies as a means of teaching physics students while studying the section "Light phenomena" in grade 9

№	Theme	Recommended mobile app
1	Light phenomena. Speed of light propagation	Physics at school
2	Light beam. The law of rectilinear propagation of light. Solar and lunar eclipse	Get a class: Smart
3	The law of rectilinear propagation of light. Task Solving	Physics at school,
4	Reflection of light. The law of reflection of light. Flat mirror	Physics at school, Science experiments in physics lab
5	Solving light reflection problems	Get a class: Smart
6	Laboratory Work № 3: Studying the Laws of Reflection of Light Using a Flat Mirror	Science experiments in physics lab
7	Refraction of light at the boundary of two media	Physics virtual lab
8	Solving Refraction Problems	Get a class: Smart
9	Laboratory Work № 4: Light Refraction Research	Physics at school
10	Decomposition of white light into colors. Color formation	Get a class: Smart
11	Lenses. Optical power and focal length of the lens	Physics at school
12	Capture images with a thin lens. The formula of a thin lens. The simplest optical devices	Physics virtual lab
13	Lenses. Tasks solving	Physics at school
14	Laboratory work № 5: Determination of focal length and optical power of a thin lens	Get a class: Smart
15	Lenses. Tasks solving	Physics at school
16	The eye is like an optical device. Vision. Vision	Physics at school


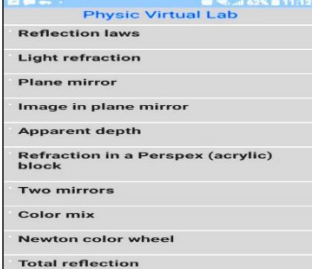
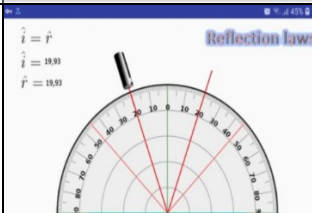
	defects and their correction. Glasses	
17	Light phenomena. Tasks solving	Get a class: Smart
18	Test № 2 Light phenomena	Get a class: Smart
19	Protection of educational projects	Each or any of them

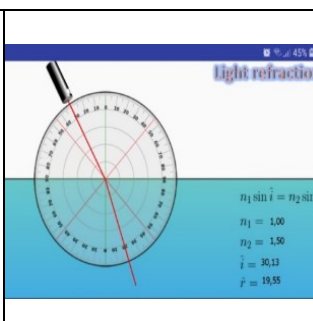
In the course of the research, a set of tasks (with step-by-step instructions for their use) was developed, aimed at the use of such mobile applications, programs, games, sites as Physics virtual lab; Science experiments in physics lab; Physics at school; Plickers; Get a class: Smart during the study of the "Light phenomena" students are aimed at developing their cognitive interest in the study of physics, and improving the quality of their learning.

The effectiveness of using the selected mobile applications is based on their features, namely:

- **Physics virtual lab** [24] - The mobile application (English version) is a virtual physics lab that allows you to test basic laws in physics using touch control. Step-by-step use of the Physics virtual lab site to study the laws of reflection and refraction is shown in Table 3.



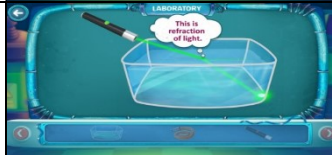
Table 3. Physics virtual lab as a tool for learning the laws of reflection and refraction of light

№	Step-by-step actions	The image on the screen
1	The menu view of the mobile application	
2	The laws of reflection and refraction of light. Choose a category: «Reflection laws»	
3	Demonstration of the law of reflection: change the angle of incidence of the beam - the angle of reflection changes automatically. Conclusion: The angle of incidence is equal to the angle of reflection.	

4	<p>Demonstration of the law of refraction of light: the beam refracts at the boundary of the air and water; the refraction angle is less than the incidence angle; changing the angle of incidence of the beam causes a change in the angle of refraction.</p> <p>Conclusion: The ratio of the sine of the angle of incidence to the sine of the refraction angle for the two media is unchanged and is equal to the relative refractive index.</p>	
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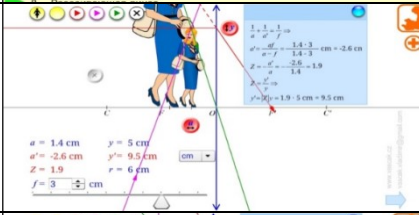
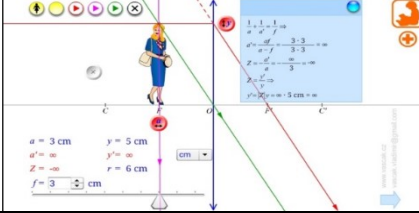
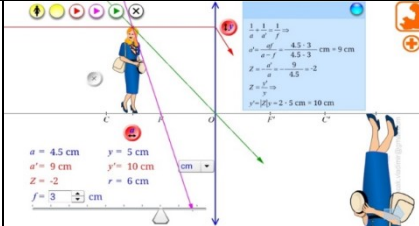
- *Science Experiments in Physics Lab* [25], a mobile application (English version), is a virtual physics lab that lets you test basic laws of physics in the form of a scientific game using touch control. In our opinion, it is one of the most successful scientific games that are suitable for all ages. Unlike the previous mobile application, there is a character in this game that acts as a guide and speaks rather slow and understandable English throughout the game. Using this app, you can achieve two goals: 1) learning to perform virtual experiments in physics; 2) to learn physics in English, to develop skill in communication in a foreign language. After the virtual experiment is followed by an audio and visual explanation. Audio explanation allows you to check the readability of the written text, to find and learn unfamiliar words. The only downside to this program is the small number of physical experiments (7 in total). But we hope that it will be improved and supplemented over time. An example of using the application as a teaching tool for physics students with a step-by-step explanation is shown in Table 4.

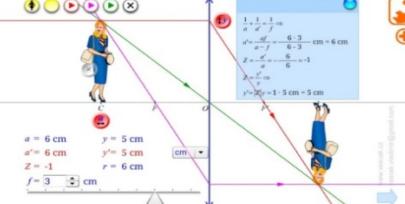
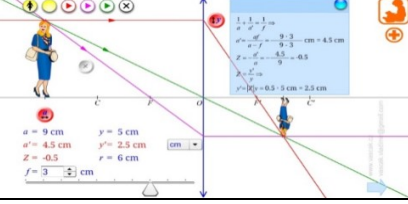
Table 4. Science experiments in the physics lab as a means of studying the theme "Refraction of light in different environments" (fragment)

№	Step-by-step actions	The image on the screen
1	We choose the theme "Refraction of light in different environments".	
2	<p>We are offered to make an experimental setup and select materials for the experiment.</p> <p>It allows you to perceive the name of objects by ear while seeing the image and name of the object on the screen.</p>	
3	<p>With the above program, we make the necessary installation, the appearance of which we see on the screen.</p> <p>We choose the angle of incidence.</p>	

- *Physics at school* [26] is a mobile application, free of charge and available for download on Google Play. The program is available in various languages (wide list). After choosing a language, 16 sections of physics themes are opened. This mobile application is no longer a game. It has the appropriate rules of use, provides that the student has some theoretical background. However, it is convenient to use this program when studying the relevant topic, both in the lesson and when doing homework. One of the main advantages of this app is the presence of mini-experiments with calculations for any topic in the school physics course; you can change the parameters of the experiment independently; vivid animations (Table 5).

Table 5. An example of using Physics at school mobile application while learning about Lenses. “Optical power and focal length of the lens”, “Capture images with a thin lens. The thin lens formula”

№	Step-by-step actions	The image on the screen
1	Choose a topic: "Collecting lens"	 <p>Оптика XII. Оптика 1. Призма 2. Субтрактивное и аддитивное смещение цветов 3. Цветовой диск Ньютона 4. Опыт Юнга 5. Зеркала 6. Линза 7. Собирающая линза</p>
2	<p>The subject is in focus. We perform construction (focal length can be changed, as well as the size of the object, and its appearance). We get an enlarged, direct, and imaginary image of the subject.</p>	 <p> $\frac{1}{a} + \frac{1}{a'} = \frac{1}{f}$ $\frac{1}{1.4} + \frac{1}{-2.6} = \frac{1}{3}$ $a' = -2.6 \text{ cm}$ $Z = 1.9$ $f = 3 \text{ cm}$ $\frac{a}{a'} = \frac{y}{y'}$ $\frac{1.4}{-2.6} = \frac{5}{y'}$ $y' = 9.5 \text{ cm}$ $r = 6 \text{ cm}$ </p>
3	<p>The subject is in the focus of the collecting lens. From the 9th-grade physics course, we know that the subject in focus will not have an image in the collecting lens.</p>	 <p> $\frac{1}{a} + \frac{1}{a'} = \frac{1}{f}$ $\frac{1}{3} + \frac{1}{a'} = \frac{1}{3}$ $\frac{1}{a'} = 0$ $a' = \infty$ $Z = \infty$ $f = 3 \text{ cm}$ $\frac{a}{a'} = \frac{y}{y'}$ $\frac{3}{\infty} = \frac{5}{y'}$ $y' = 0$ </p>
4	<p>The subject is between the focus and the dual focus of the collecting lens. We get an enlarged, inverted, true image of the object.</p>	 <p> $\frac{1}{a} + \frac{1}{a'} = \frac{1}{f}$ $\frac{1}{4.5} + \frac{1}{9} = \frac{1}{3}$ $a' = 9 \text{ cm}$ $Z = -2$ $f = 3 \text{ cm}$ $\frac{a}{a'} = \frac{y}{y'}$ $\frac{4.5}{9} = \frac{5}{y'}$ $y' = 10 \text{ cm}$ $r = 6 \text{ cm}$ </p>

5	The subject is in the second focus of the collecting lens. Get an inverted, valid, evenly sized object.	
6	The subject is behind the second focus of the collecting lens. We obtain a true, reduced and inverted image of the object.	

- **Plickers** [27] - the program consists of several applications that only work in complex form. Provides teachers work with the classroom, allows you to quickly, effectively, and visually conduct a front-line survey. Algorithm and methodological features of mobile application usage Plickers:

- register on the official Plickers.com site;
- create a class that we intend to work with and enter the names of students with numbers;
- ask four-choice questions or true-false questions. The free demo can only ask you five questions, but with multiple sets of questions, you can run them at one time;
- to identify each student, they are provided with cards with a QR code, through which students can answer questions;
- in order to provide the correct answer to the question posed by the teacher, students need to return the card with the code so that the correct answer (a, b, c, d) is on top;
- the teacher checks the Plickers mobile application by scanning the students' nameplates. On the screen of his or her phone, the teacher receives statistics of correct answers, which are given as a percentage of each question.

- **Get a class: Smart** [28] - The web site is freely available to students, teachers, and can be used on a mobile device and computer. Provides many opportunities for the study of physics 7-11 grades, has a section on preparation for the final exam. Each of the topics is selected at least 20 tasks that are solved interestingly. A character named Smart acts as an assistant throughout the training process. On the site, students can independently work the material, test, and evaluate their knowledge; the teacher can set up assignments for test work, conduct online testing during physics classes, which students can see immediately.

Through these applications, the teacher can evaluate the quality of the students' knowledge and correctly set the focus for future lessons.

Taking into account the advantages of using different mobile applications, we developed a teaching and methodological support for the study of the section "Light phenomena" in grade 9, which included lesson notes (with a description of teacher and student activities) and lessons (virtual experiments, tests, etc.) with tutorials and step-by-step instructions for teachers and students on mobile applications.

The effectiveness of the developed methodological recommendations aimed at the use of mobile technologies as a means of teaching physics students was tested by introducing it into the educational process of the OV Mishukov Kherson Academic Lyceum at the Kherson State University. The total number of students involved in the pedagogical experiment is 30.

The criterion for the effectiveness of the developed methodological recommendations for the use of mobile technologies in the educational process was chosen the level of educational achievements of 9th-grade students in physics, characterized as follows:

Beginning level: the student's response when playing the educational material is elementary, fragmentary, caused by fuzzy notions of objects and phenomena; the student's activities are carried out under the guidance of the teacher;

Intermediate level: knowledge is incomplete, superficial, the student reproduces the basic educational material, but is not well understood, has problems with analyzing and formulating conclusions; capable of performing tasks on the model;

Sufficient level: the student knows the essential features of concepts, phenomena, patterns, connections between them, apply the knowledge independently in standard situations, knows how to analyze, draw conclusions, correct mistakes. The student's answer is complete, logically justified; understanding is related to single images, not generalized;

Advanced level: the student has a deep, solid, generalized knowledge of subjects, phenomena, concepts, theories, their essential features and the connection of the latter with other concepts; able to use knowledge in both standard and non-standard situations [30].

The analysis of the distribution of 9th-grade students by levels of educational achievement, shown in Table 6, showed that there were positive changes in all levels of academic achievement of students during the study of physics. Thus, the number of students with low educational attainment decreased by 10%; the number of students with an average level of educational achievement increased by 3.33%; the number of students with a sufficient level of academic achievement has increased by 3.34%; the number of students with a high level of academic achievement in physics also increased by 3.33%.

Table 6. Level of academic achievement of 9th-grade students at the beginning and the end of the pedagogical experiment

Stage of pedagogical experiment	The level of academic achievement of students in physics								Total students
	Low		Average		Sufficient		High		
	Number	%	Number	%	Number	%	Number	%	
Start	3	10,00	14	46,67	10	33,33	3	10	30
The end	0	0,00	15	50,00	11	36,67	4	13,33	30

The differences in the distribution of students by levels of educational achievement in physics are illustrated in diagram 6 (Fig.6).

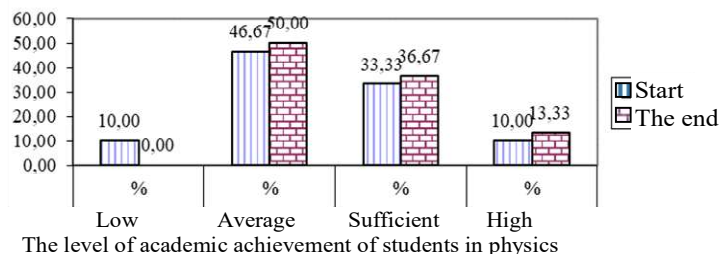


Fig.6. Distribution of 9th-grade students by levels of educational achievement in physics

The results showed that there were positive changes in the levels of educational achievement of students. The results were statistically substantiated using the T-Wilcoxon test.

So, the use of mobile technologies in Physics learning contributes to increasing the motivation of students' learning activities and enhancement of the level of educational material mastering.

4 Conclusions and Perspectives

The results of the research indicate that in the context of the active transformation of education in Ukraine, special attention should be paid to a variety of new learning methods, technologies, and techniques. The mobile technologies is a learning technology, based on the use of a wide range of digital and fully portable mobile devices (smartphones, tablets, e-books, etc.) that enable operations to receive, process and disseminate information; we propose to use it at general school, in particular, in Physics study.

The main ways to use mobile technologies in the process of teaching physics students are to use mobile applications, sites, services, cloud environments, web browsers while studying theoretical material, performing a virtual physical experiment, solving physical problems, completing homework, performing control measures (front-end polling, testing, etc.).

The prospect of further research will be development of our mobile application in physics, which will allow not only to interest students to study physics, but also to improve the quality of physical education of students.

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Comparison of Open Learning Forms in Organizational Education

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Abstract. This article describes the insights from the analysis of the comparative evaluation of open learning methods in organizational education and will be of most interest to researchers and practitioners with non-university background. The approaches considered focus on the selection of solutions based on the methods, which can be individually adapted in the future and applied, for example, by using artificial intelligence technologies to achieve organizational goals without direct human intervention. In this paper we describe the evaluation methods of the learning forms based on the principles of andragogy and consider the software specifics of investigated methods. The obtained conclusions show that the open source course, online learning communities, training with virtual reality and artificial intelligence can be successfully implemented separately and in combination according to the purposes of organizational development. However, learning with artificial intelligence has also a great potential due to the extensive knowledge base and diverse ways of knowledge mediation.

Keywords: Open learning, evaluation, organizational learning, adults.

1 Introduction

With the increasing dominance of global megatrends, scientific and economic actors reorient their activities on the needs of the net generation. The rapid digitalization affects all areas of organizations: from finance and reporting management to marketing [6-8, 49]. This tendency also applies to the field of knowledge management. The adaptation to external factors influences organizational change [5, 18, 37, 47].

Since lifelong learning became increasingly important, education is changing in the direction of globalization, digitalization, and specialization [35]. This change means mobility, and learning independent of time and place, increasing internationalization of educational opportunities, strict specification of professional fields. In many countries, lifelong learning is financially sponsored by the state and internal in the companies [50, 53]. Innovations in education have great potential and, like finance and reporting, have a significant impact on organizational management [46, 49, 51].

At the same time, this leads to increasing demand for the most current knowledge. Open education technologies fulfill all requirements: they are freely accessible, cost- and license-free, and offer users both teacher and learner role choice. Companies use open education solutions to provide their employees with transparent access to the selected general knowledge and to strengthen a common knowledge base [9, 33]. Some global corporations build their organizational learning system similar to open source platforms. Small and medium-sized companies are embracing this trend and trying to make their organizational learning digital, virtual, and open [31].

Although the open learning platforms offer most of the video content, the more often other technologies are developed and used for learning purposes there. In addition to well-known video-based training on the online platforms and open libraries, current open education includes the following forms of learning: synchronous e-learning (whiteboard, digital classrooms, open educational games), simulation (open educational virtual games), online learning communities (peer-tutoring, peer-working) [43, 54]. Furthermore, such forms for the open transfer of knowledge are virtual visualization AR-, VR-applications (learning factory), or CPU-based learning and learning with artificial intelligence intended [16]. Historically, all these forms and their particular applications correspond to the specific development of digital education and range from digitization of analog media and conventional learning methods (e. g. e-learning, cloud learning), visual integration of information into the working environment, connecting content with physical systems (e. g. augmented reality, IoT, virtual classroom) to autonomous systems of competence development by combining existing technologies and artificial intelligence (e. g. cognitive systems, collective intelligence). The learning form and their relevance for organizational development are the objects of our investigation.

Our attempt to combine different learning forms is not new, and it differs from the other firstly in the methodology of the study and secondly in the obtained results [16].

2 Research methodology

Our investigation consisted of four phases. Firstly, a trend analysis of the web search requests was performed to determine which learning forms are currently most relevant in which countries and how this tendency has developed. In the second step, we compared the selected learning forms empirically using deductive usability benchmark analysis. The third phase was based on expert evaluation according to the obtained theoretical and empirical data. Finally, we present the portfolio matrix of proposed solutions for a better identification of learning forms according to organizational learning objectives and learning efficiency.

2.1 Defining open education forms for evaluation

Even though automation with the increasing use of artificial intelligence reshapes education, traditional learning forms remain relevant. To evaluate these forms qualitative correctly, we selected one option from each group according to such criteria as technology degree, user interaction, variety of learning content, number of participants,

etc. These exemplary forms are: open source training (video), online learning communities, virtual reality and learning with and from cognitive systems. We have limited the range of our investigation to these four options.

2.2 Trend analysis of learning forms.

To determine the actuality of the topic, we conducted a definition analysis with Google Trends from the past five years worldwide with the predefined terms: “open source course”, “online learning communities”, “training with virtual reality” and “learning with artificial intelligence” [17].

2.3 Usability benchmark analysis

Between all usability analyses, we have chosen one, which aims to compare several alternatives by one user and review of results collected from all users [1]. Here the learning forms are tested in comparison based on standardized tasks. All independent variables are fixed, and the dependent variables are measured. If one learning form is better than another in a benchmark analysis, it does not mean that this also applies to a change in the independent variables, e.g., for another task or users with other previous experiences. The study aimed to evaluate forms of learning based on parameters such as the speed of knowledge transfer, quality of learning, and personal perception. The first parameter determines the time that the user needs to record the presenting content. The second parameter was measured by how effectively the user reproduces the learning material, even after one day. The third parameter reflects the user's feedback on the learning experience. The compared parameters are variable except the predetermined video duration in the first variant, open source course. The speed of knowledge transfer of other learning forms due to user interaction cannot be estimated in advance. The number of correctly answered questions measured the learning quality. A total of four open questions and one with an enumeration of the offered variants were asked. The questionnaire was conducted twice: immediately after the completion of each session and the next day. Similarly, after the completion of each learning form, the data on the personal perception of the learning process were collected. Users prioritized this according to their overall learning experience (on a scale from 1 to 4).

The subject to learn should originate from an already known learning area and contain some new information and be appropriate for a wide variety of respondent groups. This reflects the approach for learning in the organization. As the subject for this study, we have chosen planets of the Solar system, one for each learning form. It must be noted that the quantity of the learning material was the same for each learning form and the same content was taught (distance from the Sun, color of the planet surface, components of the surface, water management on the planet, possibilities to explore the planets). For the first form of learning, we filmed a short video about Venus (the presenter explained the learning material and slides) and showed it to the respondents to simulate the open space course experience. For the online learning communities, we have chosen the Earth as a learning object, because all participants already have some previous knowledge. For the third learning form, training with virtual reality, we have selected a "Weltraum VR" app (as hardware Apache VR Box), which has already integrated several tasks, among others, to learn some facts about Mars. The unique feature here is

that the learner who is virtually on the planet does not perceive the tasks as it is, but notices many things, such as the planet's surface color and substance unconsciously. For learning with artificial intelligence, we have chosen a voice assistant Siri (Mac-Book), that gave the information about Mercury. The knowledge query was in the form of a questionnaire, in which the user was asked the same questions as regarded content. Although the analysis of Google Trends shows the increasing interest in learning with artificial intelligence, we have not found a better and free solution for our purpose than voice assistance. Unfortunately, this only redirects the user to the internet pages and does not provide any comprehensive information about the searched object. It means that currently, the user has to search and sort out the information himself. Nonetheless, the variations in functionalities and the likelihood of the vision of teaching artificial intelligence continue to increase.

According to the standard rules for such survey art the selected respondent group consisted of the employed person in the age between 16 and 70 years (the lower limit for apprentices and school students and the upper limit is for persons with a lot of work experience) [11, 25]. The precondition for the users was to have little or inadequate knowledge of the planets of the Solar system. To calculate the number of required respondents to be tested, we have applied a stochastic sample formula (1) using the appropriate web tool [38]:

$$k = \frac{\frac{z^2 \times p(1-p)}{e^2}}{1 + \left(\frac{z^2 \times p(1-p)}{e^2 N}\right)} \quad (1)$$

k - number of required respondents

N - population size (since we focus on the small and medium-sized company, we set this value at 250 as the highest employee number)

e - error range as a decimal number (we define as 10%)

z - confidence level (we take $z = 1.65$ for confidence level 90%)

p - percentage as decimal number (we choose $p = 0.5$ for optimal sample size)

Hence, 54 respondents participated in our study.

2.4 Heuristic morphological analysis

The heuristic morphological analysis is suitable for the systematic study of complex issues. Furthermore, this method can be used for the formation of future scenarios. For the evaluation, the processing logic, according to Scriven, was applied [40]. The sequence of the evaluation methodology selected by us corresponds to the evaluation logic [12].

We structured the considered object (open learning form) into its parameters, for which various options are listed. By combining these options, innovative, goal-oriented approaches can be identified.

This method consists of five steps. These are:

1. Definition of the considered object (learning form).
2. Formulation of parameters for designing the requirements of the learning system for adult education.
3. Formulation of performance levels of the parameters.
4. Measurement and comparison (analysis).
5. Prioritization of objects or object components. In this step, the different results are combined into a unified value statement.

This method is presented in the form of a matrix with parameters. The characteristics of each learning form that influence the parameter values can be combined with solutions and presented as a prioritized list of possible solution combinations [36].

Defining the evaluating parameters

Through systematic literature analysis, we have selected and evaluated four parameter categories according to the investigated learning forms [2-4, 13-16, 19-22, 27-29, 32-34, 44, 52, 55]. These correspond to the requirements of andragogic, software, and organization.

Andragogical evaluation parameters include:

- problem orientation (consideration of the specific issue) - in the ICT this parameter is presented, as a sequence of problem-solving tasks;
- user interaction - integration of the adult into the learning process, involvement and active participation in the learning process;
- participant orientation - the software is adapted to predefined user groups; the subject-specific experience of the user - the interactions in ICT are designed according to the level of knowledge and are neither too much nor too little demanding;
- ability for self-paced learning - the learner can determine for himself whether the learning content is relevant for him, whether and how he can vary it;
- intermediary of the material has a supporting function and allows the learner to understand the correlations of the material and the existing knowledge (i. a. user-generated content).

Special software evaluation parameters are:

- requirement of special software - some forms of learning cannot be used without specialized hardware, and the others use it partially;
- experience with the control (control experience) - the level of recognition of the used hard- or software influences the user experience and improves the handling;
- complexity of the control (control complexity) - this parameter, similar to the experience with the control system influences many other parameters;
- control type (voice control, haptics, gesture control) - this parameter indirectly influences other parameters, such as complexity of the control, customizability and real-time use;
- customizability - adjustment or selection of control options;
- real-time application - use of a learning form at the time the user searches for the problem solution or information;
- prospects for other applications - option for use for other purposes.

General software evaluation parameters are also required for the evaluation of educational applications. They are generally valid and are not included in the evaluation we performed. These include all other facets of software required parameters.

Organizational evaluation parameters include

- ability for permanent integration into organizational learning;
- suitability for diverse users - the learning form must be applicable for different user groups;
- speed of the learning process - the learning process is not intended to reduce the work of the employees, but to support it. Learning must be effective and time efficient;
- number of learners involved – the number of learners simultaneously participating in the learning process.

Our parameter system consists of 17 parameters, which can be assigned to one of the five performance levels in the respective learning form. It means that 340 parameter values are considerable for the learning system, which is established by the organization. Since we evaluate four learning forms according to their parameter levels, only 17 values can be selected as one per parameter from a total of 68.

3 Results

Empirical results of the Google Trends analysis (see Fig. 1) show continuous regression for the interest of the definition “training with virtual reality” and gradual reduction of the search requests for “online learning communities” and “open source course”.

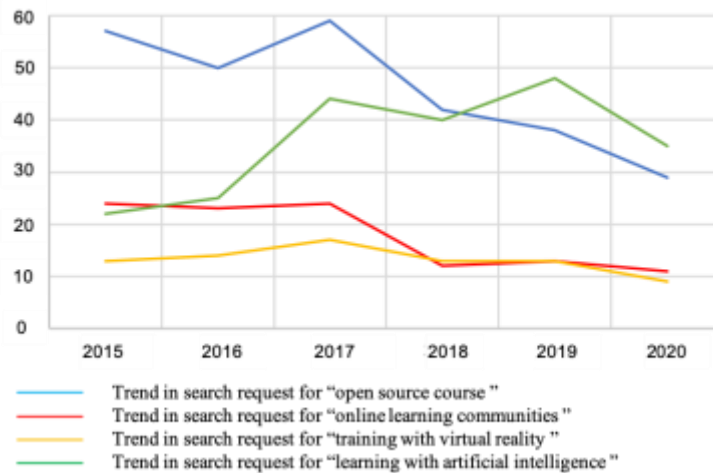


Fig. 1. Trends in the searched of definitions (own processing)

In the years 2016 and 2018, the massive increases in search requests for the definition “learning with artificial intelligence” are noticeable. These trends show that the open source issue remains highly relevant, and learning with artificial intelligence is increasingly important. The topics on online learning with communities and with virtual reality are less interesting or known to the users. We may forecast that interest in the subject of artificial intelligence usage in the learning process will continue to grow over the years until the newer technology does not massively penetrate education.

Remarkable is the geographical distribution of search requests for defined terms (see Fig. 2): the United States and India show massive popularity of these terms. This distribution does not mean that there is no interest in these definitions in the other countries, but that the search requests there are relatively low. Possible reasons for these trends can be the population of the country and the (desirable) technological development of the country. As the fragments of the results indicate, the topics of online learning communities and training with virtual reality have the greatest actuality in the United States. In comparison, the interest of Indian web-users in the issues open source course and learning with artificial intelligence is particularly high (this can be recognized by the more intensive marking of the country on the map).

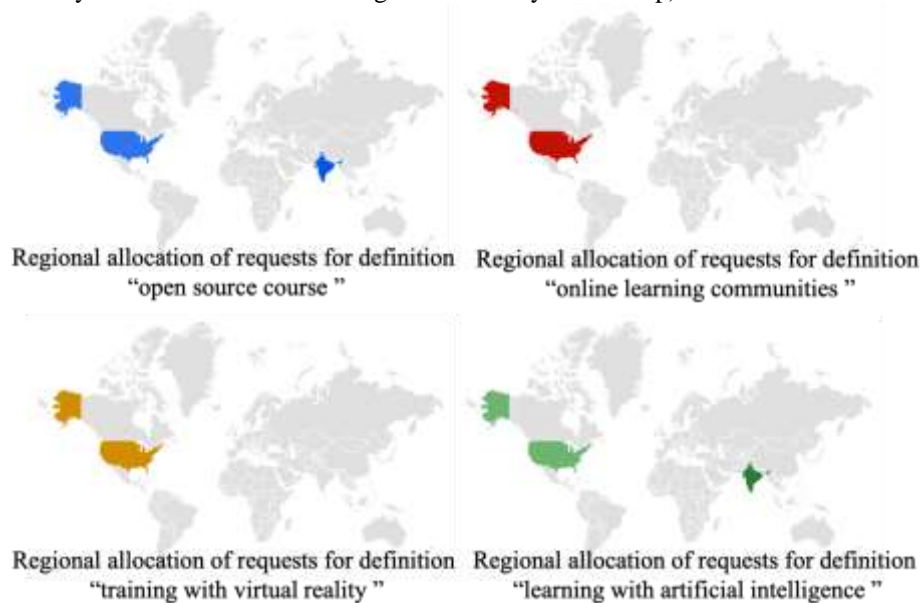


Fig. 2. Regional allocation of requests for searched definitions (own processing)

The data in Fig. 3 were obtained in the heuristic morphological analysis. The speed of knowledge transfer shows the average time in minutes required for the user to gain knowledge. The comparison of the value of this parameter indicates that virtual training is the most rapid to complete. This learning method also shows the best values for the other two parameters and, therefore, the optimal one from the examined learning forms. Other studies have already proven that active learning (by doing) is much more effective than passive learning [24].

On the contrary, learning with artificial intelligence shows the worst values, which can be the consequence of relatively poor learning performance of the solution used. Nevertheless, to the additional question, whether the users could imagine being guided by artificial intelligence in their everyday life and the organization-relevant topics in the future, we received 54 positive answers. The second-best result is measured with an open source course.

While the aggregated data is the relatively consistent, more precise observation of the individual values shows a high degree of diversification. It means that some respondents complete the tasks extremely quickly or are very imprecise in their queries and all forms of learning, which is more related to their personality or experience.

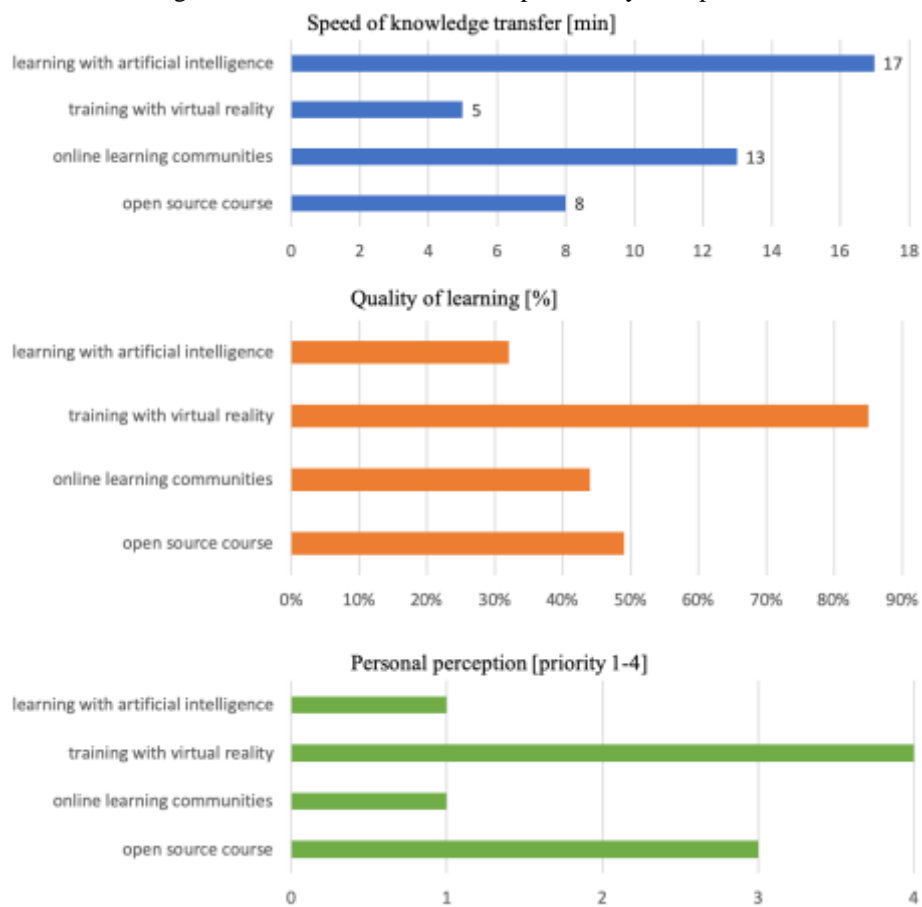


Fig. 3. Speed of knowledge transfer, quality of learning and personal perception of tested learning forms (own processing)

The advantages of this experimental procedure allow causal conclusions on the learning experience when conducted efficiently and make significant contributions to theory

formation. The disadvantage of planning an experiment involves the appropriate determination of the dependent and independent variables as well as a measured option for the test environment.

Through heuristic morphological analysis, we can achieve a quantitative illustration of individual learning form parameters and use them as a basis for the design of education systems based on the combination of selected criteria.

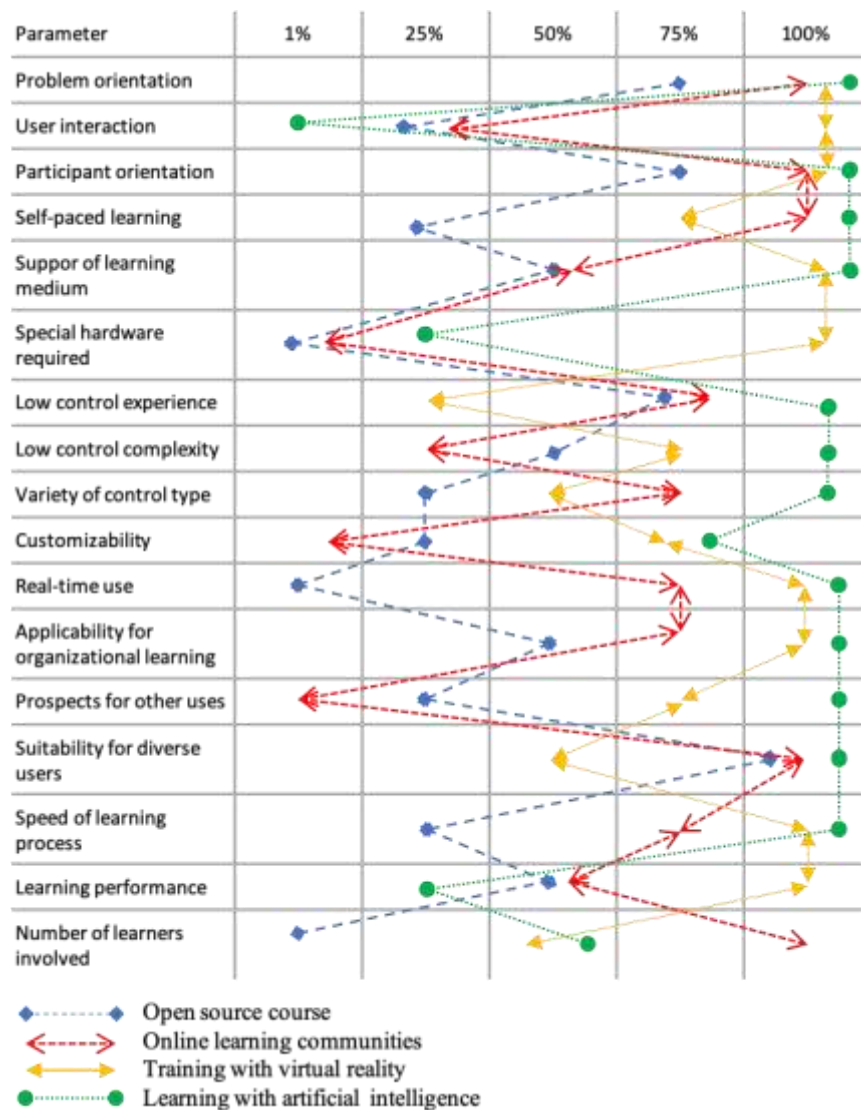


Fig. 4. Heuristic morphological analysis of different learning forms (own processing)

The analysis reveals that according to the latest scientific findings, the highest performance levels of the most parameters (12 of 17) indicate learning with artificial intelligence. 9 of 17 highly valued parameters has trained with virtual reality. Although open source course (training) does not seem to provide such high parameter values, it does not require specialized hardware and is relevant for teaching of different contents. These findings can serve to individualize the design of the organizational learning system as well as the selection of particular learning forms.

The following statements can be concluded from the findings of empirical and theoretical analyses:

- for efficient (fast, high learning performance) real-time knowledge acquisition and transfer for one person is the training with virtual or augmented reality, due to so gained immersive experience, currently the most appropriate approach (e.g., workplace-related knowledge, conflict resolution behavior in a specific situation, etc.);
- for the transfer of general, informative, non-problem-related knowledge with a high degree of standardization is open source course particularly useful (e.g., preparation for certification audit, general compliance rules);
- the learning communities offer support for issues that are difficult to resolve (e.g. maintenance-related knowledge for specific parameter settings, preparation of presentations);
- the learning with artificial intelligence can be used in various ways, for example, as a language assistant to support the quick search for problem-solving methods (reading the content aloud) or to detect the learners' weaknesses and knowledge gaps (the recognition of faulty activity execution through gesture recognition), etc.

Besides, learning with artificial intelligence can also be used for selecting appropriate forms of learning within the organization's learning system.

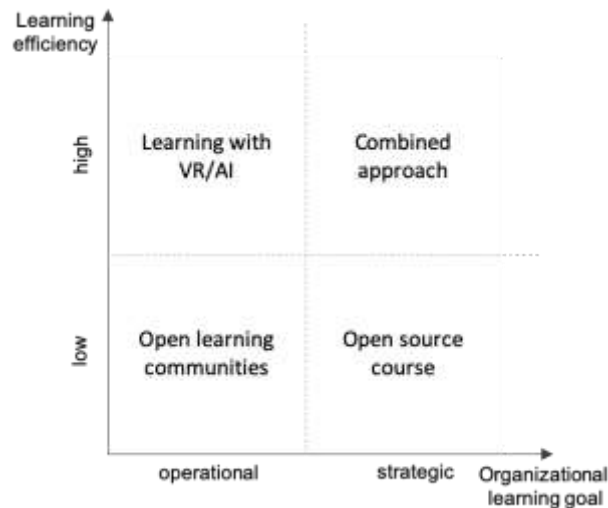


Fig. 5. Learning forms for different organizational learning goals according to the learning efficiency (own processing)

Fig. 5 provides the distribution of learning forms for organizational purposes according to the attributes learning efficiency and the goals of organizational development. It means that each organizational goal requires different learning or explanation forms. Based on these findings, organizations can individually design a customized learning model with the use of open forms.

In conclusion, the system of organizational learning must be formulated as complex of different learning methods and forms. Since almost all companies today are characterized by a high degree of diversity, the learning forms have to be adapted to the respective respondent groups, which may be necessary to convey the same knowledge through different learning forms.

4 Conclusion and discussion

Our study aimed to compare different forms of open education for organizational issues. We have found that each learning form can be ideal for a specific purpose or a particular user. Even though the considered learning methods can be easily implemented in open education platforms, the involvement of those in the organizational development process has a limitation, which mainly affects the learning material. The learning material concerns the learning context because, as soon as it refers to the proprietary corporate know-how, the content is not permitted to be publicly available. It means that only those contents which describe generally valid principles or which are not authentic components of a concept/process/product can be educated as open source with the related learning forms.

From the perspective of the cooperation, an open knowledge pool can be established for a common knowledge base because of the cooperation between companies, from which sector-specific information for open learning can be taken [42, 43].

The orientation of knowledge, research, and industrial organizations towards the digitalization of learning processes has many advantages and changes the educational state of the world [10, 39]. Nevertheless, this can be better integrated with state (financial) support [23, 30, 53].

The findings of our study can be integrated into the design for the subsystem of organizational learning [26].

Acknowledgements

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Designing a chatbot for learning a subject in a Telegram messenger

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Abstract. The article deals with Telegram messenger as a tool that can be used for educational purposes, namely, for studying the academic discipline. The essence of the concept of messenger and statistics of its use in the world are clarified. Popular messengers such as WhatsApp, Viber and Telegram are compared, as well as their technological capabilities and potential for use in learning activities. The advantages of Telegram Messenger and requirements for the software product (chatbot) were highlighted.

In the Telegram environment there was developed a chatbot for studying the educational discipline "Informatics" for the students of vocational education institutions. It was developed and described the stage of its development: creating a token API in BotFather, adding a new bot in ManyBot, as well as adding commands and responses to them, with a demonstration of illustrations. The final result of the chatbot is given, which contains such common divisions: lectures, lab, and homework.

An experimental study to test the effectiveness of using the chatbot in the learning process is made, which describes its implementation in the learning process on the example of the subject " Informatics " and conclusions about the relevance of its use in the learning process.

Keywords: Messenger, telegram, educational discipline, chatbot

1 Introduction

1.1 Formulation of the problem. Nowadays, information technologies have penetrated all spheres of life and activity of people. And the activity of a teacher and students is no exception: electronic document management, work with an electronic journal, preparation of materials for students (cards, tasks for independent and control work), training presentations for classes, as well as a significant number of methodological and training materials in electronic form, and others. Electronic learning resources are easy to use, have built-in search and navigation capabilities, and are compact and can fit in any mobile device [1].

With the rapid development of mobile learning technologies, including phones (smartphones) tablets, etc., and the ease of access to mobile Internet, as well as the rapid development of mobile software applications for the period 2017-2018r. in Ukraine have gained popularity Messengers. According to research results, 91% of smartphone owners use Messengers [2]. With the help of these Messengers, users can exchange messages, files, photos and video materials, and it allows using the functions of Messengers in education.

One of the main tasks of the education sector is to improve and develop the learning process. In the current realities, this task cannot be done successfully without introducing new mobile technologies into the learning process. Given the popularity of instant Messengers at all ages and their large volume of functions, it will be advisable to use them in educational activities.

1.2 Analysis of recent research and publications. The use of ICT in the educational process is considered in the works of Hotko O., Chaikovska O. [3], Rebenok V.M. [4]. Mobile learning technologies were considered by Tsidilo I.M., Tereshchuk S.I. and others [5], Zolotareva I.O. [6], Voichenko O. [7], Silberman M.A. [8]. Intellectual technologies in teaching were investigated by Tsidilo I.M. [9]. In the work of Matveev N.Y., Zolotaryuk A.V. [10] described the use of Telegram chatbots in different spheres of life; the prospects of using chatbots in higher education were investigated by Firsova E.A. [11]. Shyshkina M., Spirin O.M.[12] studied quality evaluation ICT.

It should be noted that the design of the Telegram chatbot for the study of academic discipline in the Telegram Messenger is a new direction of research and requires further development.

1.3 Goal. To substantiate the advantages of using the Telegram Messenger capabilities in the educational process, to design and experimentally test the efficiency of using the "Informatics" chatbot for students of vocational education institutions.

2 Presentation of the main material

2.1 Telegram among other Messengers

Messengers are instant messaging tools such as messaging, audio and video, photos, location, and more.

The most popular Messenger is WhatsApp, which is owned by Facebook, the leader of social networks. Over the course of 2018, the number of active Messenger users has reached over 1.5 billion users and is growing rapidly. According to a study [13] conducted in April 2019 (see Figure 1), Facebook Messenger is the second largest user

by WhatsApp. WeChat, QQ Mobile, Snapchat, Viber, Discord and Telegram share the following positions.

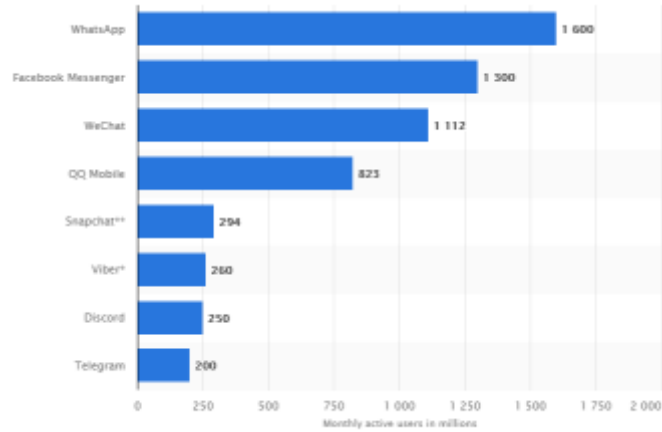


Fig. 1. The number of active users in the most popular Messengers

It should be noted that the Messengers themselves are different from each other, but they have many things in common. They are all intuitive, with the help of them you can chat from any part of the world where there is internet and gadget connection, there are group chats. Most support channels that publish news on a variety of topics. To use one or more Messengers in the learning process, it is necessary to make a comparative analysis of their technological capabilities and potential and describe their differences.

In our opinion, it will be advisable to compare the most popular Messenger in the world WhatsApp, the leader in Ukraine Viber [14], and Telegram, in our opinion, as the most promising one. For comparison, the main 4 criteria were identified:

- General information
- Users
- Contacts
- Security

In the general information (see Fig. 2) we have identified the following comparison criteria:

- PC accessibility (allowing users to use the application on their computer)
- Show ads (in-app advertising can be distracting and compelling)
- Free application (possibility to install the application for free)
- Personalization (ability to change background, color)

	WhatsApp	Viber	Telegram
PC accessibility	+	+	+
Show ads	+	-	+
Free application	+	+	+
Personalization	+	-	+

	4/4	2/4	4/4
--	-----	-----	-----

Fig. 2. Comparison of general Messengers information

The criterion “Users” (Fig. 3) contains the points for comparison:

- Access the application by password (possibility to set password to Messenger)
- Two-factor authentication (dual password verification)
- The size of the starting files
- Cloud file storage (when deleting information, it can be restored from cloud storage)

	WhatsApp	Viber	Telegram
Access the application by password	-	-	+
Two-factor authentication	+	-	+
The size of the starting files	64mb.	200mb.	1500mb.
Cloud file storage	-	-	+
	1/4	0/4	4/4

Fig. 3. Comparing Messengers by Users

Figure 4. shows a comparison of Messengers on the criterion "Contacts", namely:

- Bilateral rejection function (before receiving a message from a stranger, the user can reject the message)
- Use GPS to meet people (you can see who is nearby, making it easier to meet people)
- Phonebook contacts integration (ability to contact phonebook contacts)
- Maximum length of voicemails (ability to send long voicemails)

	WhatsApp	Viber	Telegram
Bilateral rejection function	+	-	+
Use GPS to meet people	-	-	+
Phonebook contacts integration	+	+	+
Max. length of voicemails	15 min.	30 sec.	60 min.
	2/4	1/4	4/4

Figure 4. Comparison of instant Messengers on the criterion "Contacts"

Security is one of the main characteristics of Messengers, so the following points have been identified for the equation (see Figure 5):

- Two-way encryption (protects data and ensures that only the recipient can access the information).
- Presence of privacy setting (the ability to set content so that it is not all available for public viewing).
- Possibility of anonymous use.

	WhatsApp	Viber	Telegram
Two-way encryption	+	-	+
Presence of privacy settings	-	-	+
Possibility of anonymous use	-	-	+
	2/3	0/3	3/3

Fig. 5. Comparing Messengers by Security

Based on the survey, WhatsApp scored 9 points, Viber 3 points, Telegram 15 points. On the graph (see Fig. 6) graphically shows the strengths and weaknesses of Messengers.

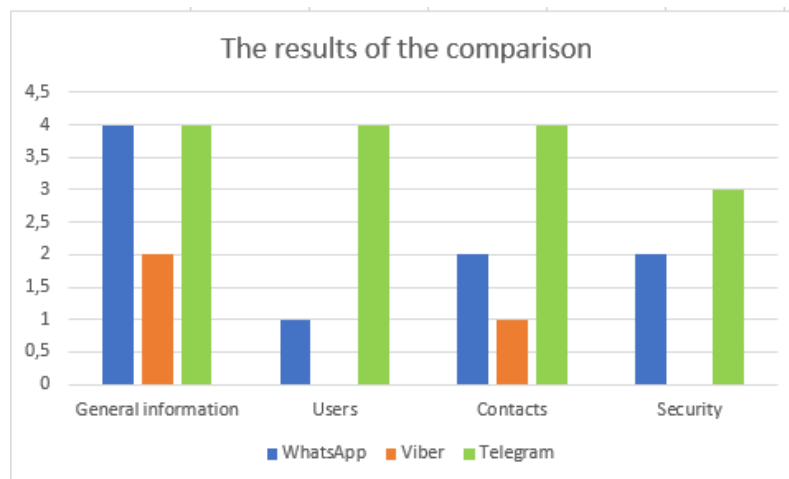


Fig. 6. Comparison results

As the review of modern Messengers, they are an important part of modern communication in the network. Users prefer convenient, cheap and fast communication, so choose instant Messengers. Of course, there are a large number of applications of this type, however, Telegram has the highest growth rate of the number of active users, it is the most functional and relevant for use as a means of training.

Distinguishes Telegram from other Messengers and the possibility and simplicity of creation of bots and channels with different by assigning functions. Through which you can get reminders, pass tests, download materials, study in your free time.

2.2 Designing a Chatbot on the discipline of "Informatics"

Using the chatbot function in Telegram, the task is to design and develop a software product (chatbot), in a Telegram environment with which one might consider theoretical materials, homework, view performance examples and to find a task to laboratory work on the discipline "Informatics".

Let us select the basic requirements that have been delivered to the software product (chatbot):

- Chat bot should disclose the essence, to cover the basics of the course "Informatics";
- The material should be as clear as possible;
- The interface of the developed product should be adaptable and convenient in viewing not only on the computer, but also on mobile phone (smartphone);
- Availability of self-control;
- The chatbot should contain laboratory work and homework assignments.
- The software product must be intuitive and contain useful links.

Before you create a bot, you need to register it in BotFather. This is done in order for the bot to work in the Telegram. BotFather- this is also a bot, find it simply, it requires the search menu write BotFather and find it in the list. Further you need to press the bottom button "run" (Fig. 7).

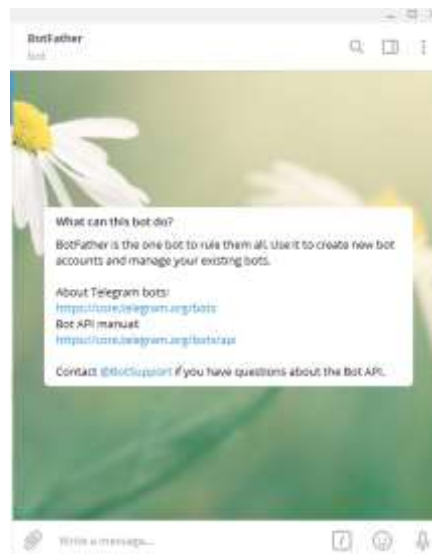


Fig. 7. Registration In Botfather

The Chat window displays all the available commands. We are interested in /Newbot. You can enter it manually or click on the appropriate entry directly in the command list. BotFather will ask you to choose a name for your future bot. Enter arbitrary.

Next, you need to come up with username Botu. It should be unique, because otherwise registration bot will be rejected. At the end of the name must be specified box _bot.

After successful registration, the BotFather will send you a message with the token, which you need to record somewhere in your own and save. In the future, we will need it.

Now registering a bot in the BotFather is crossing to the creation of the bot.

ManyBot is a unique development in Telegram that allows users without knowledge of programming languages to create their bots.

To create your bot run a ManyBot, the principle of launching a similar botfather, click on the button "Add a new bot" (Fig. 8).

Then copy the previously obtained token in BotFather and insert into the chat with ManyBot. Click on the arrow to send the message to the right or Enter.

Now you need to write a little text about what our bot will do. In case you do not want to write anything, you can use the "Skip" button.

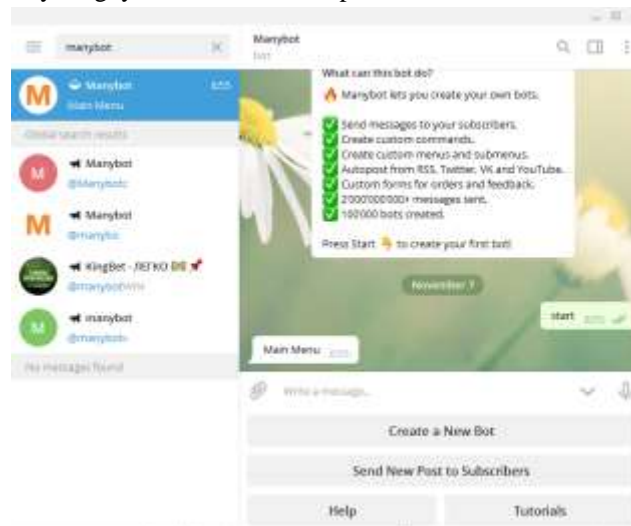


Fig. 8. Adding a new bot to the Manybot

The next step click on the "Run", immediately opens a window where a list of commands is displayed, and at the bottom of a convenient menu to add functions to the bot. Click on the button "custom Commands" and then "Create a command". The name of the command is arbitrary, but that it is then understood, what it corresponds to. Before the team, make sure to specify the slash.

After writing a command, click Enter or the blue arrow on the right. Now you need to add what we want the bot to send to the user in response to the command entered. For example, some text or picture, document or audio file.

However, the manual command to enter is inconvenient each time, so you can use the Create graphical menu function in ManyBot. To do this, go back to the section

"Custom Commands" and click on the button "Configure a goal. menu. Then click on the button "Add menu item". Choose in the menu created by us command. Enter the name of the menu item. For example, "lectures". You can use *Emodji*.

Press Enter or on the arrow on the right. You see a message that the command was successfully added to the menu. Return with the corresponding button (2 clicks).

The menu now has a button added by us, which is fixed by the established command.

Thus, the functionality of the T-Bot is formed. The final result on the Fig.9.

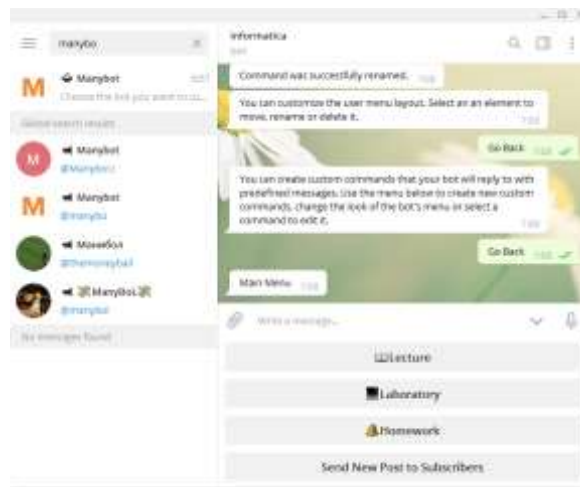


Fig. 9. Ready Chat bot for the subject "Informatics"

2.3 Experimental verification of the effectiveness of the use of the chat bot in the learning process

To check the effectiveness of chatbot usage during training, namely: use of the chatbot made for the subject "Informatics", was carried out by experimental research at Chortkiv Pedagogical College named after. Barvinskyi. In particular, in group 45 on the subject "Informatics" was conducted in the III stages of the experiment, which included:

1. **The first step is:** conducting a conversation, acquaintance, and informing for students and teachers, namely: installation of Messenger Telegram, connection of the chatbot, and use of its functions.
2. **Experimental work:** The use of chatbot in the educational process and, for the subject "informatics".
3. **Result analysis:** summarizing by survey.

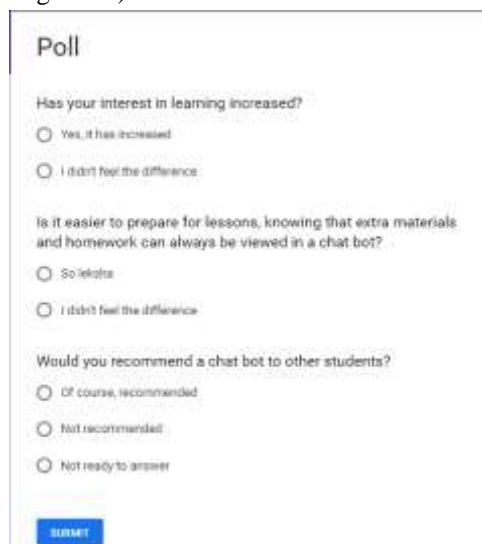
During the experimental work, students had 2 class in the subject "Informatics", which studied the topics: "Information model. Stages of solving problems on a computer " and " Creating algorithms using US and pseudo code ". It should be noted that from 1 class of our experiment, all students had a Telegram Messenger installed and all students and teachers were connected to the created bot.

The first class was attended by 10 students from the I subgroup, and 11 students from the II subgroup, 3 were absent. The teacher was explaining a new topic, showing a presentation, the students were mostly taking notes in a notebook. At the end of the class the teacher from his laptop sent a bot to the "Lecture" presentation on the topic, and to "Homework" homework. Students clicking on the team received relevant information. Also in the next class in the calendar, there should be laboratory work. The teacher added lab work to the Laboratory menu, and warned students that they could familiarize themselves with the lab work at home through a chatbot.

It was fun to watch the result for the next class because all students have the opportunity to get acquainted with and even to start doing the laboratory work on their own, to make it easier to do it in class, as well as for missing students from the first class, whether they have mastered the material and what are in them will be the results of laboratory work.

On the 2nd class there were 2 students were not on the previous class. The teacher handed out lab work assignments, the students sat down at the computer and began to do the work. The very first thing the teacher noted was that there were almost no questions at the initial stage of the work, and the questions came only near the end of the work. Two students of "Honors" completed the work in the middle of the lesson, the teacher gave them additional tasks, most of them coped by the end of the lesson, including those students who were absent for the last class. When a teacher asked students or assisted you with a chatbot in learning new material and learning about lab work, students responded positively.

After a week of experimental research, students were interviewed on the Google Forms platform (see Figure 10).



The image shows a screenshot of a Google Forms poll. The title is "Poll". There are three questions, each with two radio button options. The first question is "Has your interest in learning increased?" with options "Yes, it has increased" and "I didn't feel the difference". The second question is "Is it easier to prepare for lessons, knowing that extra materials and homework can always be viewed in a chat bot?" with options "So/leisure" and "I didn't feel the difference". The third question is "Would you recommend a chat bot to other students?" with options "Of course, recommended", "Not recommended", and "Not ready to answer". At the bottom of the form is a blue "SUBMIT" button.

Fig. 10. Student Survey

According to the survey (see Fig. 11) 94.7% of students noted that they have increased interest in learning and it became easier to prepare for the classes. They would recommend using a chatbot for other students as well as 94.7% of respondents.

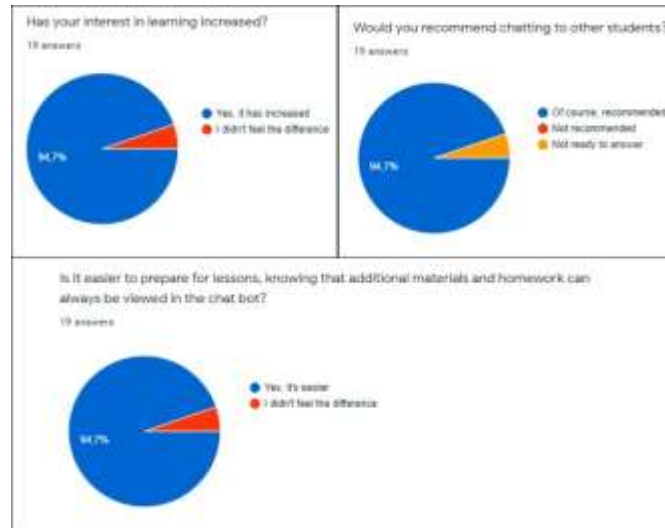


Fig. 11. Survey Results

For example, the use of the Messenger for the subject "Informatics" is the opportunity to use it for each training subject separately or in a general training chatbot. Each teaching-dacha can create a separate chatbot for its subject and add all students of the group. After the class, as a reminder, the teacher sends the text of the homework in the chatbot. The teacher may refer to literature or upcoming conferences on the subject. Students can send tasks to the chatbot, at the same time getting acquainted with the work of colleagues, or, conversely, not to see them - depending on the type of homework. Training can be conducted and completely remotely, without full-time classes. Convenient to use during quarantine when students do not attend class and receive assignments via chatbot. The main function of the Telegram may be to send a course message and then collect and verify the completed homework.

3 Conclusion

Undoubtedly, mobile education is playing an increasing role in the modernization and improvement of Ukrainian education. That is why Ukrainian educational institutions should focus on improving the provision of educational services by gradually integrating mobile learning technologies into the educational process. Telegram is a convenient free communication tool for students and teachers that will accelerate and simplify their interaction. Students will be able to take home lectures,

view homework, and share with others on Telegram on the way home. As the pilot study showed, students are interested and ready to use the chatbot to study the course.

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